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ART. I.—*Contributions to Meteorology, being results derived from an examination of the Observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Eighth paper. With plates I and II.

[Read before the National Academy of Sciences, New York, October 24, 1877.]

The origin and development of storms.

IN order to determine the circumstances under which storms originate, and ultimately acquire their full intensity, I selected from the published volumes of the Signal Service observations (September, 1872, to May, 1874), all those cases in which the barometer fell below 29·25 inches at any station. It was found that the barometer on Mt. Washington was frequently very much lower than at the neighboring stations, Burlington and Portland, indicating some peculiarity of this station. All these cases were therefore set aside, and reserved for separate examination. During the entire period under discussion, the mean height of the barometer at Virginia City was nearly a third of an inch lower than at the neighboring stations, and these observations were therefore eliminated from my list. There remained one hundred and forty-eight cases in which the barometer fell below 29·25 inches at some one of the other stations. Sometimes at the same hour the barometer was below 29·25 inches at a considerable number of stations all included within the same low area. In such cases only one of the stations is included in the table, viz., the station at which the barometer was lowest. These one hundred and forty-eight cases correspond to forty-four different storms, and are shown in the following table, in which column 1st shows the number of the storm; column 2d shows the date at which the barometer was below 29·25 inches; column 3d shows the least height of the barometer observed at that hour; column 4th shows the

name of the station at which the given height was observed; column 5th shows the total rain-fall (in inches) for the preceding eight hours, at all the stations included within the area of low barometer; column 6th shows the date of the storm's origin so far as can be determined from the observations; column 7th shows the locality where the storm originated. In order to reduce the dimensions of the table, the localities are denoted by symbols whose significance is explained on page 5. Column 8th shows the total rain-fall (in inches) for the eight hours preceding the date in column 6th, at all the stations included within a circle of six hundred miles in diameter, inclosing the locality named in column 7th; column 10th shows the direction of an area of high barometer on the east side of the locality where the storm originated; column 11th shows the distance of this high pressure in miles, and column 9th shows the height of the barometer at that point. Columns 12, 13 and 14 show similar particulars on the west side of the locality named in column 7th. Several additional columns which I had prepared, I am obliged to omit in order to reduce the table to the limits of the page of this Journal.

Barometer below 29·25 inches.

No.	Date.	Bar. lowest.	Station.	Rain in low.	Storm originated. When.	Storm originated. Where.	Rain-fall.	High on East side. Bar.	High on East side. Direction	High on East side. Dist.	High on West side. Bar.	High on West side. Direction.	High on West side. Dist.
	1872.												
1	Nov. 7.2	29·12	Portland, Me.	6·00	Nov. 3	Wy.	0	30.25	S. 70° E.	850	30·18	N. 72° W.	925
	7.3	·13	Quebec	2·43									
	8.1	·07	Quebec	6·75									
	8.2	·19	Quebec	·25									
2	30.1	·10	Quebec	2·26	Nov. 28	n. Mi.	0	·38	S. 56 E.	600	·71	West	550
3	Dec. 24.1	·15	Portland, Or.	1·84	Dec. 23	n. W.		·70	East	1250			
4	27.1	·17	Halifax	·75	Dec. 23	G. M.	0	·35	East	680	·70	N. 12 W.	1100
	1873.												
5	Jan. 2.2	·23	Milwaukee	6·09	Jan. 1	N. M.	0	·42	N. 80 E.	1675	·15	N. 82 W.	900
	2.3	·07	Milwaukee	5·62									
	3.1	·09	Marquette	8·12									
6	27.3	·17	Halifax	·74	Jan. 25	Col.	0	·36	East	1060	·17	West	915
7	29.2	·15	Fort Garry	0	Jan. 28	n. Mo.	0	·72	S. 54 E.	920	·18	West	600
8	Feb. 6.2	·20	Fort Garry	2·54	Feb. 5	n. Mo.	0	·30	S. 49 E.	1600	·41	S. 20 W.	1100
9	8.1	·15	Halifax	2·05	Feb. 6	Ala.	1·39	·29	N. 62 E.	650	·48	N. 79 W.	2000
	9.3	·20	Halifax	·20									
10	21.1	·19	Buffalo	7·56	Feb. 20	N. M.	·01	·34	N. 70 E.	1100	·59	N. 62 W.	1200
	21.2	·04	New London	6·89									
	21.3	·17	Portland, Me.	1·17									
	22.1	·22	Quebec	1·09									
	22.2	·14	Quebec	·52									
	22.3	·17	Quebec	·72									
	23.1	·18	Quebec	·92									
	23.2	·18	Quebec	·08									
	23.3	·23	Quebec	·40									
	24.1	·24	Quebec	·33									
11	Mar. 15.2	·13	Grand Haven	4·69	Mar. 14	Dak.	·02	·46	S. 78 E.	930	·36	West	1050
	16.1	·16	Montreal	1·05									
	16.3	·23	Quebec	0									

Barometer below 29·25 inches.

No.	Date.	Bar. lowest.	Station.	Rain in low.	Storm originated. When.	Storm originated. Where.	Rainfall.	High on East side. Bar.	High on East side. Direction	High on East side. Dist.	High on West side. Bar.	High on West side. Direction.	High on West side. Dist.
	1873.												
2	Mar. 21.1	29·19	Portland, Me.	4·63	Mar. 16	n. Mo.	0	30·44	S. 58° E.	820	30·14	S. 40° W.	900
	21.2	·19	Portland, Me.	1·78									
3	26.3	·16	Portland, Me.	2·98	Mar. 23	n. T.	0	·41	N. 16 E.	960	·14	N. 74 W.	1200
	29.2	29·01	Oswego	10·42	Mar. 26	n. Mo.	0	·37	S. 84 E.	650	·11	S. 41 W.	900
	29.3	28·80	Burlington	5·73									
4	30.1	28·87	Portland, Me.	2·78									
	30.2	29·20	Portland, Me.	1·40									
5	Aug. 24.2	29·03	Halifax	1·12	Aug. 23	A. O.	0				·36	N. 54 W.	1000
	24.3	28·99	Halifax	·72									
6	Sept. 25.3	29·18	Yankton	1·70	Sept. 23	Dak.	0	·11	S. 83 E.	435	·10	West	1080
	26.2	·20	Fort Garry	5·13									
7	Oct. 6.2	·10	Punta Rassa	6·40	Oct. 5	Cub.	.01				·39	N. 33 W.	1600
	6.3	·02	Punta Rassa	5·46									
8	17.2	·23	St. Paul	5·94	Oct. 16	n. D.	0	·31	S. 70 E.	680	·41	West	1200
	17.3	·02	Duluth	3·14									
9	27.2	·22	Portland, Me.	8·41	Oct. 25	Col.	·04	·50	N. 74 E.	710	·47	N. 72 W.	920
	Nov. 8.2	·14	Eastport	5·10	Nov. 4	n. W.	0	·42	East	1200			
10	8.3	29·12	Halifax	2·21									
	9.1	28·96	Cape Rosier	1·56									
11	13.1	28·99	Cape Rosier	3·78	Nov. 10	Neb.	0	·24	N. 73 E.	440	·38	West	850
	17.1	29·00	Wilmington	3·91	Nov. 13	n. Mo.	0	·35	S. 31 E.	1520	·12	S. 16 W.	440
	17.2	28·82	Norfolk	7·23									
	17.3	28·82	Cape May	5·32									
12	18.1	28·66	New London	8·23									
	18.2	28·47	Eastport	9·12									
	18.3	28·64	Chatham	2·16									
	19.1	28·97	Cape Rosier	1·98									
	24.3	29·09	Eastport	3·14	Nov. 21	N. M.	0	·39	S. 82 E.	1460	·14	N. 52 W.	1090
	25.1	28·82	Halifax	4·31									
13	25.2	28·80	Sydney	2·79									
	25.3	28·78	Sydney	0·66									
	26.1	28·85	Sydney	0·78									
	26.2	29·17	Sydney	0·07									
14	Dec. 3.3	29·08	Escanaba	13·99	Nov. 30	Mon.	0	·70	S. 83 E.	1650			
	4.1	28·91	Marquette	3·67									
15	14.1	29·14	Sydney	0·95	Dec. 11	N. M.	0	·37	S. 82 E.	1500	·28	N. 51 W.	1090
	28.1	28·93	Portland, Me.	2·52	Dec. 24	n. W.	·09	·51	East	1075			
16	28.2	28·91	Eastport	4·29									
	28.3	28·98	Sydney	·49									
17	31.2	29·23	Fort Garry	·00	Dec. 29	n. W.	0	·63	S. 74 E.	1400			
	1874. 2.2	·09	Fort Sully	·33	Dec. 31	n. Mo.	0	·64	S. 60 E.	1750			
18	Jan. 2.3	·16	Fort Sully	·47									
	3.1	·05	Omaha	·35									
	3.2	·14	Marquette	1·32									
19	15.1	·15	Chatham	1·56	Jan. 13	Ark.	·10	·50	N. 76 E.	900	·87	N. 47 W.	720
	15.3	·23	Portland, Or.	·43	Jan. 14	P. O.	·01	·96	East	1070			
	16.1	·11	Portland, Or.	·78									
20	16.2	·06	Portland, Or.	·41									
	16.3	·14	Fort Benton	·21									
	17.1	·00	Fort Garry	·59									
21	Feb. 4.1	·03	Halifax	·39	Jan. 31	N. M.	·03	·64	N. 55 E.	950	·20	N. 82 W.	900
	4.2	·03	Sydney	·54									
	10.3	29·06	Halifax	66	Feb. 8	G. M.	·04	·54	N. 20 E.	1480	·22	N. 70 W.	750
22	11.1	28·78	Sydney	·79									
	11.2	28·84	Sydney	·44									
	11.3	29·13	Sydney	·30									
	11.2	·21	Fort Sully	·34	Feb. 9	P. O.	0	·54	S. 81 E.	1200			
23	11.3	·17	Fort Garry	·76									
	12.1	·15	Leavenworth	·27									
	12.2	·08	Dubuque	·96									
	12.3	·13	Escanaba	2·20									

Barometer below 29·25 inches.

No.	Date.	Bar. lowest.	Station.	Rain in low.	Storm originated. When.	Storm originated. Where.	Rain-fall.	High on East side. Bar.	High on East side. Direction	High on East side. Dist.	High on West side. Bar.	High on West side. Direction.	High on West side. Dist.
	1874.												
	Feb. 16.3	29·09	Quebec	1·76	Feb. 12	Or.	0	30.53	East	1060			
34	17.1	·07	Cape Rosier	·30									
	17.2	·12	Cape Rosier	·06									
35	Mar. 1.2	·23	Fort Garry	·02	Feb. 28	n. Mo.	0	·38	S. 72° E.	1800	30·25	S. 15° W.	45
	1.3	·05	Fort Garry	·09									
	6.2	·23	Keokuk	4·45	Mar. 3	Mon.	0	·30	N. 70 E.	730	·21	S. 18 W.	89
	6.3	·16	Dubuque	4·26									
	7.1	·17	Milwaukee	7·78									
	7.2	·24	Alpena	3·98									
	8.2	·22	Eastport	2·38									
	8.3	·19	Quebec	1·66									
	9.1	·24	Quebec	2·32									
	9.2	·13	Sydney	1·07									
	9.3	·07	Eastport	·92									
	10.1	·03	Eastport	1·41									
36	10.2	·10	Eastport	·99									
	10.3	·12	Father Point	1·56									
	11.1	·16	Sydney	1·13									
	11.2	29·01	Sydney	1·12									
	11.3	28·90	Sydney	·31									
	12.1	28·87	Cape Rosier	·91									
	12.2	28·90	Cape Rosier	·14									
	12.3	28·85	Cape Rosier	·40									
	13.1	28·86	Cape Rosier	·56									
	13.2	29·00	Cape Rosier	·66									
	13.3	29·12	Cape Rosier	·09									
	16.2	29·12	Fort Sully	6·85	Mar. 13	Mon.	·03	·41	East	740			
	19.2	29·19	Quebec	1·77									
37	19.3	28·97	Father Point	1·23									
	20.1	29·15	Sydney	·21									
	20.2	·24	Sydney	·08									
38	April 12.2	·17	Fort Sully	·40	April 11	Ut.	0	.45	N. 54 E.	940			
	12.3	·24	Fort Sully	·32									
	26.1	·13	Boston	6·34	April 23	G. M.	·07	·17	N. 15 E.	1200	·12	N. 70 W.	150
39	26.2	·23	Eastport	3·19									
	26.3	·14	Halifax	1·92									
	27.1	·14	Sydney	·71									
	30.1	29·11	Father Point	3·00	April 26	Wy.	0	·24	N. 66 E.	770	·19	West	65
	30.2	28·97	Father Point	1·66									
40	30.3	29·11	Quebec	·54									
	May 1.1	·05	Father Point	·46									
	1.2	·22	Father Point	·88									
	April 30 2	·13	Fort Sully	·43	April 29	Dak.	0	·38	East	620			
	30.3	·20	Fort Sully	·01									
	May 1.2	·16	Fort Sully	·08									
41	1.3	·23	Omaha	·11									
	2.1	·25	Omaha	1·56									
	2.2	·17	Leavenworth	2·62									
	8.2	·05	Fort Sully	·51	May 7	Mon.	0	·23	S. 54 E.	1370			
	8.3	·12	Fort Sully	·04									
42	9.1	·17	Fort Sully	·92									
	9.2	·01	Fort Sully	2·04									
	9.3	·15	Fort Sully	·92									
	25.1	·24	Alpena	7·08	May 21	Dak.	0	·20	S. 80 E.	440			
43	25.2	·17	Ottawa	8·78									
	25.3	·24	Ottawa	5·19									
	26.2	·16	Fort Sully	·06	May 25	Mon.	0	·20	S. 36 E.	550			
44	27.2	·16	Fort Sully	3·14									
	27.3	·24	Fort Sully	2·64									

Of these forty-four storms, thirty-two occurred during the five months from November to March, and only two occurred during the four months from June to September.

The third column of the following table shows the number of cases in which a storm originated in each of the different localities named in column 2d. The first column shows the letters by which the locality was designated in column 7th of the table on pages 2 to 4.

Symbol.	Where storm originated.	Cases.	Symbol.	Where storm originated.	Cases.
P. O.	Pacific Ocean, north of Washington Territory.	2	n. D.	North of Dakota.	1
n. W.	North of Wash'n Terr.	4	Dak.	Dakota.	4
Or.	Oregon.	1	Neb.	Nebraska.	1
Ut.	Utah.	1	n. T.	Northern Texas.	1
n. Mo.	North of Montana.	7	n. Mi.	North of Michigan.	1
Mon.	Montana.	5	Ark.	Arkansas.	1
Wy.	Wyoming.	2	G. M.	Gulf of Mexico.	3
Col.	Colorado.	2	Ala.	Alabama.	1
N. M.	New Mexico.	5	Cub.	Near Cuba.	1
			A. O.	Atlantic O., near lat 37°.	1

We see that, of the forty-four storms here recorded, two apparently came from the Pacific Ocean north of the United States boundary; four others came from nearly the same locality; one came from Oregon and one from Utah; that is, eight appear to have had their origin on the west side of the Rocky Mountains. Of the thirty-six remaining cases, seven appear to have originated north of Montana, five in Montana, two in Wyoming, two in Colorado, and five in New Mexico; that is, twenty-one appear to have originated upon or very near to the chain of the Rocky Mountains. Seven other cases appear to have originated west of the meridian of 95° from Greenwich, viz: one north of Dakota, four in Dakota, one in Nebraska and one in Northern Texas. Six other cases appear to have originated west of the meridian of 83° from Greenwich, viz: one north of Michigan, one in Arkansas, one in Alabama and three in the Gulf of Mexico. Besides these, one appeared to originate near Cuba, and one in the Atlantic Ocean not far from Cape Henry. We thus see that our great storms are not confined in their origin to any particular locality, but half of them originate upon or very near the chain of the Rocky Mountains. More than two-thirds of the whole number originate north of latitude 36°.

The first stage in the development of each of these storms was an area several hundred miles in diameter, over which the height of the barometer differed but little from thirty inches, with an area of high barometer both on the east and west sides, and at a distance of about 1,000 miles. In the few cases in which a high barometer is not reported on both sides of the origin, it is

because the area of the observations was not sufficiently extended. The mean value of the high barometer on the east side was 30·42 inches, and the mean distance 1,033 miles; on the west side the values were 30·31 inches and 977 miles. If the area of the observations had been sufficiently extended towards the north, it is presumed there would sometimes have been found three areas of high barometer within a distance of 1,000 miles from the locality where the storm originated. On Hoffmeyer's storm charts we frequently find three areas of high barometer and occasionally four areas of high barometer surrounding an area of low barometer.

These areas of high barometer are regarded as one of the causes, and generally the most important cause of the storm which succeeds. Two such areas of high barometer create a tendency of the air towards an intermediate point, and the currents thus set in motion are deflected to the right by the earth's rotation, whence results a diminished pressure over the central area. This diminished pressure causes a still stronger inward flow of the air, which results in a still greater depression of the barometer. Since the air presses in on all sides towards this area of low barometer, the area tends to assume an oval form, which may become sensibly circular if the winds are very violent, and the centrifugal force resulting from this revolving motion causes a still further depression of the barometer. This partial vacuum would be soon filled, and the inward movement of the air would cease were it not for an upward motion by which the inflowing air escapes. The air in its upward motion, carrying with it a large amount of aqueous vapor, is cooled, and its vapor is condensed, producing rain. The heat which is liberated in the condensation of this vapor causes a further expansion of the air, and increases the force of the inward movement of the wind. Rain is then one of the circumstances which increases the force of a storm, and it invariably attends storms when they have attained to considerable violence, as is shown by the rain-fall in column 5th of the table on page 2. This table generally shows a large rain-fall whenever the storm is so situated as to permit observations on its eastern side; but when the center of the storm passes eastward beyond our stations of observation, the observed rain-fall rapidly diminishes. See Nos. 1, 9, 10, 11, 23, 34, 36 and 37.

I have shown in my 7th paper, pp. 14, 15, that an area of low barometer of considerable magnitude may be formed and continue for several days with very little rain; but in these cases the barometer was never observed to fall as low as 29·25 inches; and it will be noticed that some rain was invariably reported whenever the barometer fell below 29·4 inches, and

generally there was some rain reported whenever the barometer fell below 29·5 inches. I have found no storm of great violence which was not accompanied by a considerable fall of rain. Rainfall is not, however, generally the cause of that first movement of the wind which results in a great barometric depression. This appears from column 8th of the table on page 2, which shows that over a circle of 600 miles in diameter surrounding the locality where the storm originated, in thirty-one cases no rain for the preceding eight hours was reported from any station, and in only one instance did the total rain-fall within this circle exceed one-tenth of an inch. It may be said that in the neighborhood of these localities the stations were few in number, and that rain-fall may have occurred at intermediate points from which we have no reports. But in at least a quarter of all the cases, this circle of 600 miles in diameter included as many as four or five stations, so that we seem fully justified in concluding that generally the inward movement of the air toward a central area begins before there is any considerable precipitation of vapor.

After an area of low barometer has been formed, it soon begins to change its position. This movement appears to be mainly determined by the same causes which control the general circulation of the atmosphere. Throughout the United States (with the exception of the extreme southern margin) the average annual progress of the wind is from west to east, and this movement is determined by causes which are general in their operation, and cannot be permanently changed by the influence of local storms. When an area of low barometer is formed, the wind sets in both from the east and west sides to restore the disturbed equilibrium. The partial rarefaction of the air causes an inward pressure of the wind on the east side which is balanced by an equal pressure of the wind from the west side arising from the same cause. But on the west side there is an additional pressure eastward resulting from that cause which determines the general circulation of the atmosphere, and which would exist even if there were no local disturbance. This pressure is not limited to the center of the storm, but extends to the entire mass of air which is disturbed by the storm, and generally extends much beyond these limits, and at all points is exerted nearly in parallel lines. Moreover, the disturbance of the atmosphere by storms is mainly confined to the lower half of the atmosphere, while the regular movement of the upper half is much less disturbed. The force of this upper current from the west, combined with that of the lower half of the atmosphere, pressing upon the west side of an area of low barometer tends to fill up the depression upon that side. On the east side of the storm, it is mainly the lower portion of

the atmosphere which presses inward, while the upper portion is still moving from the west. Thus while under the influence of the earth's rotation upon the inflowing current, the barometer is continually falling on the east side of the storm, the pressure is being restored on the west side; that is, the center of least pressure advances in the direction of the general system of atmospheric circulation. This reasoning applies not merely to the easterly motion of storms in middle latitudes, but also to the westerly motion of storms within the tropics.

There is a third circumstance which appears to have an important influence upon the progress of storms in the middle latitudes. The upward motion of the air which always prevails within an area of low barometer takes place principally on the east side of the low center, as is indicated by the position of the rain-areas described in my 7th paper. By this upward motion, the air which presses in upon the east side of the low center is prevented from restoring the equilibrium of pressure upon that side, while there is less of this upward movement on the west side of the low center. Thus the low center is steadily transferred toward the east, or the storm travels eastward.

The areas of high barometer which uniformly mark the commencement of a storm, invariably attend it during its progress eastward. During the progress of the storms recorded in the table on page 2, the average value of the high barometer on the east side was 30·39 inches, and on the west side 30·32 inches, which numbers are almost identical with the values found for the commencement of the storms, showing that although the wind had been blowing outward from these areas of high barometer for several days, the magnitude of the high barometer had not been diminished. Hence we conclude that these areas of high barometer must be constantly recruited by air which flows toward them in the upper regions of the atmosphere, and this supply evidently comes from the areas of low barometer. In other words, during the progress of storms, the surface winds are moving from areas of high barometer toward areas of low barometer; and the upper winds are moving from areas of low barometer toward areas of high barometer.

An inspection of column 4th of the table on page 2, shows that these cases of low barometer occur most frequently in the neighborhood of the Atlantic Ocean. This will appear from the following table, in which the stations are divided into three classes; one class including the stations near the Atlantic coast or the Gulf of St. Lawrence, a second class including the stations between the preceding class and the meridian of 92° from Greenwich, the third class including stations west of the meridian of 92°.

Near the Atlantic coast.			From the coast to long. 92°.			West of longitude 92°.		
Station.	Lat.	Cases.	Station.	Lat.	Cases.	Station.	Lat.	Cases.
Cape Rosier	48° 52′	11	Marquette	46° 33′	3	Fort Garry	49° 51′	8
Father Point	48 31	6	Escanaba	45 46	2	Fort Benton	47 52	1
Chatham	47 3	2	Montreal	45 31	1	Duluth	46 48	1
Quebec	46 48	17	Ottawa	45 26	2	Portland, Or.	45 30	4
Sydney	46 8	17	Alpena	45 5	2	St. Paul	44 53	1
Eastport	44 55	9	Grand Haven	43 5	1	Fort Sully	44 39	17
Halifax	44 39	11	Milwaukee	43 3	3	Yankton	42 45	1
Burlington	44 29	1	Buffalo	42 53	1	Omaha	41 16	3
Portland, Me.	43 40	9	Dubuque	42 30	2	Leavenworth	39 19	2
Boston	42 21	1	Oswego	42 28	1			
New London	41 22	1	Keokuk	40 23	1			
Cape May	38 56	1						
Norfolk	36 51	1						
Wilmington	34 11	1						
Punta Rassa	26 29	2						

We see that cases of low barometer occur most frequently at the northern stations, and none have occurred south of latitude 39° except on the Atlantic coast. The cases of low barometer appear to be pretty uniformly distributed along the different meridians until we come within two hundred miles of the Atlantic coast, with but one exception, viz., Fort Sully. There is reason to suspect that in 1874 the readings of the barometer at this station were too low. During the first six months of 1874 the mean height of the barometer at this station was more than one-tenth of an inch below that of the neighboring stations Duluth, Breckenridge and Yankton. If we apply this correction to the observations reported at Fort Sully, the number of cases at this station below 29·25 inches will be reduced to four, which accords very well with the results at other western stations. The observations at Cape Rosier, Father Point and Sydney did not commence until November, 1873, and those at Chatham in October, 1873. There is then a sudden increase in the violence of storms on approaching the Atlantic coast, and this may be ascribed to the increased supply of aqueous vapor coming from the ocean and the Gulf Stream. This increased supply of vapor results in an increased fall of rain; that is, increased expansion of the air, causing an increased violence of the wind, and hence diminished pressure.

In nine of the cases included in the table on page 2, the velocity of the wind was reported zero, and in thirty-one cases the velocity did not exceed five miles per hour, showing that near the center of an area of low pressure there is usually a period during which the air is almost entirely calm.

In fifty-three of the cases included in the table, no rain was reported for the preceding eight hours at the station where the barometer was lowest; and in seventy-eight of the cases the

rain-fall was less than one-tenth of an inch, showing that the principal rain-fall does not take place at the center of a low area, but considerably to the east of that center.

An area of low barometer may have considerable progressive motion when there is no rain-fall, as is shown in several examples quoted in my 7th paper; but the abundant rain-fall which usually accompanies great barometric depressions tends greatly to modify the movement of the storm's center. Since this rain-fall takes place chiefly on the east side of the low center, the heat which is liberated in the condensation of the aqueous vapor causes a stronger inflow of air on the east side and a continued fall of the barometer on that side. If there should be a great precipitation of vapor on the west side of the center of least pressure, this must be accompanied by ascending currents of air on that side which would oppose the establishment of the equilibrium of pressure on that side, and the center of the storm may be held stationary or even diverted to the west. This appears to afford the explanation of the phenomenon of stationary storms, of which No. 36 in the table on page 2 is a very remarkable example. This storm traveled from Montana to Nova Scotia at the rate of twenty-four miles per hour; but from March 9th to March 10th, when near Nova Scotia, its motion did not exceed three miles per hour. From the 10th to the 11th its motion was scarcely fifteen miles per hour, and from the 11th to the 14th the center oscillated to and fro, its average rate of progress for the three days being less than three miles per hour. This period was characterized by a heavy fall of snow on the west side of the center of low pressure, as is shown by the following table.

Precipitation, March 9–14, 1874.

	9.1	9.2	9.3	10.1	10.2	10.3	11.1	11.2	11.3	12.1	12.2	12.3	13.1	13.2	13.3	14.1	Sum.
Rochester	·13	·11	·01	·10	·03		·02	·01		·22	·04	·02	·10	·09	·03	·04	·95
Montreal	·40	·10		·03	·20	·20	·07					·01	·01				1·02
Ottawa	·20	·10		·10	·10		·30	·10									·90
Quebec	·20		·30	·10	·20	·20	·10					·20					1·30
Father Point		·01	·05	·35	·05	·02				·33							81
Cape Rosier	·57	·03	·19	·26	·19			·10	·15	·05		·10	·30	·10			2·04
Chatham		·17	·30	·15									·01	·01			·64

The date is given at the top of each column, and the precipitation, which was chiefly in the form of snow, is expressed in inches of water. We see that during these five days the average precipitation was more than one inch of water, which corresponds to about one foot of snow, and this snow-fall extended westward 1,000 miles from the center of least pressure, and there was considerable precipitation even beyond these limits. This remarkable precipitation of vapor which continued so long and

extended over so large an area on the west side of the low centre, is believed to have been the cause of the slow eastward progress of the storm.

This unusual precipitation on the west side of the storm is ascribed in part to an east wind which prevailed at a moderate elevation above the earth's surface, while a strong wind from the west or northwest prevailed at the surface of the earth. This fact is shown by the following observations of the wind and the upper clouds at Portland, Eastport and Halifax.

Date.	Station.	Wind.	Clouds.
March 11.2	Eastport	N. W.	E.
11.2	Halifax	N. W.	S.
11.3	Halifax	W.	S.
12.1	Eastport	N. W.	E.
12.1	Portland	W.	N. E.

The precipitation on the west side of the low center ceased March 14th, and after that date the low center traveled rapidly eastward. From the 14th to the 15th its average progress was twenty-nine miles per hour, from the 15th to the 16th it was forty-seven miles per hour, from the 16th to the 17th it was thirty-six miles per hour, from the 17th to the 18th it was only thirteen miles per hour, and from the 18th to the 19th when off North Cape it was only eight miles per hour. The progress of this storm from Montana to the North Cape is shown on Chart I, and the isobaric curves show that there was a sudden increase in the violence of the storm on approaching the Atlantic coast.

No. 10 of the table on page 2 presents another example of a nearly stationary storm. From February 22d to the 24th the center of this storm remained for forty-eight hours near Quebec, and for the next two days the storm traveled very slowly, but I have no means of determining the exact position of the low center. The following observations show that at this time there was an unusual precipitation on the west side of the storm's center.

Precipitation, February 22–26, 1873.

	22.1	22.2	22.3	23.1	23.3	25.1	25.3	26.1	Sum
Mt. Washington	·15		·50	·32			·45	·50	1·92
Quebec	·40	·50	·20		·30	·01		·61	2·02

No. 40 of the table on page 2 presents another example of the same kind. The center of this storm remained near Father Point from the morning of April 30th for about two days, and it was four days in reaching St. Johns, Newfoundland. In

this case also there was an unusual precipitation of vapor on the west side of the center of low pressure, as is shown by the following table:

Precipitation, April 30–*May* 3, 1874.

	30.1	30.2	30.3	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	Sum
Montreal	·06				·80			·01				·87
Quebec	·50	·40	·50	·30				·10				1·80
Chatham	·21	·02		·12	·06	·02	·31	·12	·06	·04		·96
Cape Rosier	·21	·27	·01			·10	·15	·40	·20	·20		1·54
Sydney	·34	·23								·11	·09	·77

A still more remarkable example of the same kind occurred on the Atlantic Ocean in the winter of 1874–5. A storm of unusual violence extended entirely across the Atlantic, and for many days the center of the storm was nearly stationary. On the 30th of December, 1874, there was a low center (barometer 28·7 inches) a short distance south of Greenland, with an area of high pressure on the east (barometer 30·5 inches) and an area of high pressure on the west (barometer 30·8). On the 31st the low center occupied nearly the same position (barometer 28·3), with a high on the east (bar. 30·7) and a high on the west (bar. 30·8). January 1st the low was nearly stationary (bar. 28·7), with a high on the east (bar. 30·5) and a high on the west (bar. 30·7). January 2d the low had advanced 750 miles eastward (bar. 28·9), with a high on the east (bar. 30·5) but the high on the west had nearly disappeared under the influence of a low area approaching from the west. January 3d the low had advanced nearly 400 miles further east (bar. 28·7), with a high on the east (bar. 30·5) and another low on the west (bar. 28·9) followed on the west side by a high (bar. 30·5). January 4th the two low areas had blended into a single low area (bar. 28·9), and the center of least pressure was thereby transferred about 400 miles westward, with a high on the east (bar. 30·5) and a high on the west (bar. 30·7). There was at this time a subordinate low center (bar. 29·7) further east, and it may be claimed that this was the continuation of the storm of December 30th, but it appears to me more reasonable to consider the great depression of January 4th to be the continuation of that of December 30th. January 5th the low center had moved a little southward (bar. 28·9) with highs both east and west. January 6th the low had moved toward the northwest (bar. 28·9) with highs both east and west. January 7th the low had moved considerably to the south (bar. 28·5) with highs both east and west. January 8th the low was nearly stationary (bar. 28·5) with a high on the east, but the high on the west was nearly broken down by a new area of

low pressure which was advancing from the west. January 9th the low area was nearly stationary (bar. 28·7), with a high on the east much reduced (bar. 30·3) and an equal high on the west. January 10th low stationary (bar. 28·7) with a high on the east (bar. 30·5), with a small low on the west (bar. 29·5) and a high further west (bar. 30·6). January 11th the two low areas coalesced and the resulting center of least pressure was thereby carried 650 miles westward (bar. 28·5), with a high on the east (bar. 30·7) and a high on the west (bar. 30·4). In this case there was a subordinate low center (bar. 29·3) about 2,000 miles in a northeast direction, which has the appearance of having been detached from the larger low area since the morning of January 10th, and this may perhaps be claimed as being the continuation of the great storm of the twelve preceding days; but it seems to me most reasonable to regard the greater low area as being the continuation of that of December 30th. January 12th the low was stationary (bar. 27·9), with a high on the east (bar. 30·7) and a high on the west (bar. 30·5). The barometer had now attained its greatest depression, and the area of low pressure (below 30 inches) stretched entirely across the Atlantic Ocean, including the whole of Newfoundland on the west and the whole of Great Britain on the east, extending southward to latitude 32° and northward beyond latitude 70°. Plate II represents the isobars for January 12th and also the path of the storm's center from December 30th to January 18th. January 13th the center was nearly stationary, January 14th it had moved a little eastward, January 15th it had moved a little northward, and during the three following days it moved a little eastward. Thus on January 18th the center of the storm was only 900 miles eastward of its position on December 30th, and it was 200 miles westward of its position January 3d. The principal westerly motion of the storm center appeared to result from the influence of another low center advancing from the west and uniting with the former. This result took place January 4th and again January 11th, and also January 15th.

This entire period of twenty days was characterized by winds of hurricane violence on the western side of the low center, attended by extensive precipitation, which on the western side consisted chiefly of snow and sleet, with very low temperature, the thermometer on the American coast remaining much of the time near zero of Fahrenheit, and at stations but little removed from the coast sinking more than 20° below zero. This precipitation is believed to have taken place chiefly over the ocean, where its amount could not be measured. The following table shows the precipitation in Newfoundland, New Brunswick and its vicinity, and also shows the lowest tempera-

ture observed each day at two of the stations in New Brunswick and one in Manitoba.

	Precipitation, Jan. 1–18, 1875.						Lowest Temperature.		
	St. Johns.	Sydney.	Charlottet'n.	Fredericton.	Chatham.	Quebec.	Fredericton.	Chatham.	Winnipeg.
Jan. 1		0·04					— 1°·4	— 0°·5	—16°·6
2		·16	0·35	0·48	0·75	0·40	— 3·3	— 3·0	—27·8
3	1·00	·49	·35	·75	·25		6·5	— 1·0	—26·3
4		·01					— 9·5	— 6·6	—22·9
5	·10	·06	·01				— 3·4	—10·0	—30·4
6							—12·6	—11·3	—29·5
7		·03	·10		·06	·12	— 6·5	—11·3	—24·5
8	1 20	1·55	1·60	·93	1·45	·40	— 6·5	— 5·6	—45·5
9		·10	·15		·28	1·00	—13·1	—15·3	—39·2
10	1 00	·31	·15	·15	1·12		— 1·8	— 4·6	—33·8
11	·10					·01	—20·7	—16·3	—36·0
12	·02						—28·9	—17·0	—36·3
13				·60	·01	·70	—15·8	—14·3	—36·5
14	·25	·36	·55	·02	·64	·30	1·8	0·0	—34·7
15							— 7·5	— 8·8	—29·9
16	·40						— 3·3	0·5	—31·1
17	·30		·09		·09		— 1·8	— 1·3	—34·2
18							— 5·4	— 6·5	—34·8
Sum	4·37	3·11	3·35	2·93	4·65	2·93			

Over the Atlantic Ocean near the parallel of 30°, throughout the month of January the mean height of the barometer is about 30·1 inches. During the twenty days now under examination there were only four days in which the pressure in that region fell below 30·3 inches. Throughout these twenty days there was always an area of high pressure on the east, varying from 30·3 to 30 7 inches, generally at a distance of 1,500 to 2,000 miles. On five days the center of greatest pressure was distant at least 3,000 miles, but there was always a pressure of at least 30·3 inches within a distance of about 2,000 miles. On the west there was always an area of high pressure varying from 30·4 to 30·8 inches, and generally at a distance of about 1,500 miles; but on five days its distance was about 3,000 miles. It is not known whether there was an area of high pressure on the north, but we know that during this period the temperature at the north was extremely low. Throughout this entire period there was therefore a cause to produce a wind from four different directions towards the center of this storm, and the force was sufficient to set the air in motion over an immense area. The usual phenomena attending areas of low barometer must therefore follow, viz: high winds, a fall of the barometer, and a precipitation of vapor. On the present occasion these phenomena were exhibited in unusual intensity, because the center of low pressure was directly over the Gulf

Stream, where the temperature of the water in January is nearly 60°, and the air which flowed in from the north and west was excessively cold. It seems probable that this cold northwest wind pushed under the warmer wind from the southeast as was observed in the storm of March 11, 1874, and that this was one cause of the unusual precipitation on the west side of the storm-center. This extensive precipitation on the west side of the low center is believed to have been the principal cause of the slow progress of the storm eastward.

Violent Winds.

In order to determine the laws which govern the velocity of the wind I selected from the published volumes of the Signal Service observations (September, 1872, to May, 1874,) all those cases in which the velocity of the wind amounted to forty miles per hour. The number of these cases was 250, excluding the observations at Mount Washington and Pike's Peak, where high velocities are very common. Of these 250 cases, eighty-two were reported at 7:35 A. M., ninety-one at 4:35 P. M., and seventy-seven at 11 P. M. These results indicate a slight influence of the regular diurnal inequality in the force of the winds, but the inequality depending upon the hour of the day is only one-fifth as great as is found in the average of the daily observations for an entire year; showing that the causes which determine the force of the daily winds have but little influence in controlling the force of the most violent winds.

The following table shows the average number of cases of violent winds for each month of the year:

Month.	Cases.	Month.	Cases.	Month.	Cases.
Jan.	22	May	5	Sept.	3
Feb.	12	June	1	Oct.	6
March	21	July	3	Nov.	23
April	20	Aug.	2	Dec.	9

Thus we see that during the six months, from November to April, violent winds are more than five times as frequent as during the other six months of the year. But the average force of the daily winds for the former period is only one-fourth greater than during the latter period, showing, as before stated, that the causes which determine the force of the daily winds have but little influence in controlling the force of the most violent winds.

The following table shows the number of cases in which the wind blew from each of the eight principal points of the compass at the time of these high velocities. We see that violent winds come from a northern quarter two and a half times as frequently as they do from a southern quarter, and they seldom come directly from the south.

North	43 cases.	South	6 cases.
Northeast	48 "	Southwest	33 "
East	23 "	West	26 "
Southeast	19 "	Northwest	52 "

The following table shows all the stations at which these violent winds were reported in more than two cases, and it also shows the number of cases for each of the eight principal points of the compass:

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Sum.
Quebec		33	9			9	4	1	56
Breckenridge	4			9				15	28
Indianola	22	1							23
Fort Sully	6		5	1			1	5	18
Yankton	2	1	2			1	1	8	15
Cape Rosier		3	1	2		4		1	11
Father Point		1	2				3	4	10
Fort Benton						5	1	1	7
Eastport		5	2						7
Escanaba				3	2	1			6
Pembina								5	5
Grand Haven							4		4
Cheyenne							2	1	3
Milwaukee						1	1	1	3
Keokuk				1		1	1		3
Omaha	1				2				3
Knoxville	1					2			3
Fort Gibson						1		2	3
Galveston	2							1	3
Key West	1	1			1				3

The observations at Cape Rosier and Father Point embrace only a period of seven months. A comparison of all the observations indicates a decided preponderance of high velocities at the more northern stations. In order to determine whether the force of the wind generally increases with an increase of latitude, I determined the mean velocity of the wind at all the Signal Service stations and classified the observations according to the latitude of the stations. The following table shows the results at all the stations north of latitude 30°, except Mount Washington and Pike's Peak:

Latitude.	Number of stations.	Average veloc. miles per hour.
30°–34°	15	7·07
35°–39°	26	8·57
40°–44°	36	9·16
45°–49°	10	8·28

These observations indicate that in North America the average force of the wind increases with the latitude from latitude 30° to latitude 45°. Beyond the parallel of 45° there is apparently a diminution in the force of the wind, but this result may be due to the circumstance that beyond this line all the

stations are inland stations, where the force of the wind is generally less than it is upon the Atlantic coast. The average force of the wind is generally greatest at stations on the Atlantic coast, the Gulf of Mexico and the Great Lakes, particularly Lakes Michigan and Erie. The force is least at the interior stations distant from large bodies of water, a result which is naturally ascribed to the resistance to the movement of the air caused by the inequalities of the earth's surface. There is, however, an important exception to this rule between the meridian of 94° and the Rocky Mountains, where the mean force of the wind is greater than it is at the interior stations east of that meridian. Between the meridian of 94° and the Rocky Mountains, the average velocity of the wind is 10·2 miles per hour, while between the meridians of 82° and 94° the average velocity is only 7·5, and at the stations situated directly on the Mississippi river the average velocity is only 7·4 miles. This difference is partly due to the circumstance that beyond the meridian of 94° the face of the country is nearly a plane surface almost entirely destitute of forests, and therefore opposes but little resistance to the free motion of the winds. But there is another circumstance which contributes to the same result. Throughout an extensive region east of the Rocky Mountains the annual rain-fall is very small. The winds of this region are therefore dry winds, while the air of the Mississippi valley contains an abundance of vapor. The difference in the specific gravity of the air over the two localities is sufficient to accelerate considerably the west and northwest winds which sweep over the dry prairies west of the Mississippi river.

The same causes which affect the average velocity of the winds affect also the frequency of occurrence of the most violent winds. The region where violent winds are of most frequent occurrence is near the Gulf of St. Lawrence. It has been mentioned that the observations at Cape Rosier and Father Point embrace a period of only seven months, and should therefore be multiplied by three in order to render them comparable with observations at the other stations. An important reason for the greater violence of the winds in this region, is the greater magnitude of the barometric fluctuations and the unusual contrast which exists between the warm and moist winds from the south, and the cold dry winds from the north.

Beyond the meridian of 94°, where the average force of the wind is greatest, violent winds are also of very frequent occurrence, and these violent winds come from the north four times as frequently as they do from the south. Throughout this region, northerly winds sometimes prevail from British America continuously to the Gulf of Mexico. An example of this kind occurred April 7, 1873, when the wind at Indianola was fifty-

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four miles per hour, and also November 18th, 1873, when the wind at Indianola was fifty miles per hour. In these and many similar cases, there was an area of high barometer in Dakota, causing northerly winds at all places on the south side of this center from Dakota to the Gulf of Mexico. The frequency of violent winds in this region is ascribed to two causes, viz., the country is generally destitute of forests and the air is uncommonly dry.

The frequency of violent winds at Indianola is specially remarkable. In order to discover the cause of this phenomenon I have prepared the following table, in which column 1st shows the dates at which the winds attained a velocity of forty miles per hour; column 2d shows the velocity observed; column 3d shows the direction of the wind; column 4th shows the height of the barometer; column 5th shows the rain-fall in inches during the preceding eight hours; column 6th shows the temperature of the air at Indianola; column 7th shows the average temperature of the water of the Gulf of Mexico during the same month as derived from Maury's thermal charts; column 8th shows the difference between the temperature of Indianola and the temperature of the water in the Gulf; column 9th shows the height of the barometer at some station north of Indianola; column 10th shows the direction of this station; and column 11th shows its distance in miles from Indianola.

Violent winds at Indianola.

	Wind.		Barom.	Rain.	Thermometer.			High on North.		
	Vel.	Direc.			Ind'a t'mp.	Gulf t'mp.	Differ.	Barom.	Direction.	Dist.
1872, Oct. 7.1	43	N.	29·99	0·13	70°	82°	−12°	30·23	N. 45° W.	1200
Nov. 6.2	40	N.	29·71	·16	57	78	−21	·15	N. 43 E.	750
7.1	41	N.	29·83	·02	53	78	−25	·31	N. 45 W.	1200
14.1	46	N.	30·06	0	41	78	−37	·87	N. 31 W.	1500
14.2	48	N.	30·14	0	49	78	−29	·88	N. 31 W.	1500
Dec. 10.1	40	N.	29·86	2·14	47	74	−27	·65	N. 32 E.	690
1873, Jan. 28.1	43	N.	30·20	·05	30	74	−44	·82	N. 7 E.	750
28.2	46	N.	30·33	0	23	74	−51	·74	N. 7 E.	750
28.3	42	N.	30·42	0	20	74	−54	·72	N. 7 E.	750
Feb. 22.3	48	N.	30·17	0	54	74	−20	·43	N. 10 W.	1100
Mar. 2.1	41	N.	30·24	0	50	75	−25	·93	N. 10 W.	1100
25.1	52	N.	29·91	0	57	75	−18	·76	N. 10 W.	1100
25.3	44	N.	30·32	0	48	75	−27	·44	North	1200
April 7.3	54	N.	29·93	0	48	81	−33	·42	N. 10 W.	1100
15.1	41	N.	30·19	0	56	81	−25	·51	N. 31 W.	1500
Nov. 18.1	50	N.	29·95	0	58	78	−20	·42	N. 10 W.	1100
Dec. 3.3	48	N. E.	30·16	0	57	74	−17	·26	N. 31 E.	300
12.3	40	N.	30·22	0	57	74	−17	·46	N. 45 W.	1200
1874, Jan. 4.1	48	N.	30·12	·15	49	74	−25	·50	N. 4 W.	970
4.2	40	N.	30·25	0	44	74	−30	·47	N. 10 E.	500
April 1.1	44	N.	30·17	0	43	81	−38	·31	N. 10 E.	500
8.1	42	N.	29·70	·08	55	81	−26	·46	North	1400
17.1	40	N.	30·05	0	58	81	−23	·38	N. 32 E.	1300

We see that in each of these cases there was an area of high barometer on the north, and this pressure was generally sufficient to urge the wind with considerable force towards Indianola. We also see that in each case the temperature of the air at Indianola was below that of the water on the south side, and generally very much below it; and moreover the air over the Gulf contained an abundance of vapor. This cause alone would be sufficient to produce a fresh breeze from the north at Indianola.

The reason that violent winds are more common at Indianola than at stations further east on the Gulf of Mexico may be the greater dryness of the air near the Rocky Mountains. The annual rain-fall decreases from the Mississippi River to the Rocky Mountains, and the winds must be dryer near the mountains than they are near the Mississippi River. We find a corresponding increase in the mean velocity of the winds as we advance westward from Mobile. At Mobile the mean velocity of the wind is 6·0 miles per hour; at New Orleans it is 7·3 miles; at Galveston it is 9·3 miles; and at Indianola it is 13·7 miles.

At several of the stations, one of the most noticeable peculiarities of these violent winds is the great predominance of winds from a particular direction, viz: at Quebec they come chiefly from the northeast; at Breckenridge chiefly from the northwest; at Indianola from the north; at Yankton from the northwest, etc. This seems to indicate that the direction of the wind is somewhat modified by the configuration of the surface of the surrounding country.

A high velocity of the wind is not invariably associated with a low barometer. In fifty-seven cases (out of 250) the barometer was above thirty inches; in sixteen cases it was above 30·25 inches; and in three cases it was as high as 30·5 inches. The following are the extreme cases:

No.	Date.	Stations.	Barom.	Wind.		Temp.
				Direc.	Force.	
1	1873, Jan. 27.2	Breckenridge	30·75	N.	40	−17°
2	Jan. 15.2	Quebec	30·56	N. E.	41	7
3	1872, Dec. 22.3	Breckenridge	30·50	N. W.	40	−23

In each of these cases there was an area of low barometer within the limits of the United States, and also an area of high barometer; but in cases No. 1 and No. 3 the pressure at Breckenridge was the highest reported at any station at that hour. In No. 1, however, the barometer at Breckenridge rose ·17 inch and in No. 3 it rose ·20 inch before the succeeding observation, which seems to indicate that at the former date the center of high pressure was northwest of Breckenridge. In

No. 1 there was a difference of temperature of 84° between Breckenridge and Florida, and in No. 3 a difference of 89°. This was doubtless an important part of the moving force which gave the wind such velocity. Nos. 1 and 3 are remarkable examples of the force with which a cold wave often sweeps over Montana and Dakota, bringing at the same time an extremely low temperature and a very high barometer. In No. 2 the barometer indicated 30·91 inches at Halifax, and the difference of temperature between Quebec and Florida was 69°.

Barometric Gradient.

I have determined the barometric gradient for each of the 250 cases of high velocity of the wind, and a comparison of the results shows that the gradient increases with the latitude of the station. In order to determine the rate of increase, I divided the observations into four classes; the first containing all the stations south of latitude 35°; the second containing the stations between latitude 35° and 40°; the third between 40° and 45°; and the fourth containing the stations north of latitude 45°. The following table shows the average results; column first shows the average latitude of the stations in each class, and column second shows the average distance in miles between the isobars drawn for each tenth of an inch difference of pressure:

Latitude 29°·3	Distance 98 miles.
" 37 ·5	" 66 "
" 42 ·7	" 62 "
" 47 ·7	" 50 "

It is readily seen that the gradient increases more rapidly than the sine of the latitude, but not so rapidly as the square of the sine of the latitude. It also appears that the gradient is about the same in the Mississippi valley as it is near the Atlantic coast in the same latitude, with the exception of the stations which have a great elevation. At an elevation of 6,000 feet the gradient is nearly one-third less than it is at the lower stations.

The observations also indicate that the gradient is less in summer than in winter; but the observations are too few in number to furnish a satisfactory value of the gradient in summer for these high velocities.

The following table shows in miles the average distance between the isobars (which are drawn to represent a difference of pressure of one-tenth of an inch), corresponding to a velocity of the wind from one to fifty miles per hour, excluding the observations at stations south of latitude 36°. The average latitude of the stations employed is about 45°. The first part of the table is taken from my second paper, page 13.

Relation between the velocity of the wind and the distance between the isobars.

Veloc.	Dist.	Veloc.	Dist.	Veloc.	Dist.	Veloc.	Dist.	Veloc.	Dist.
1	134	11	115	21	97	31	78	41	50
2	134	12	114	22	97	32	75	42	49
3	134	13	109	23	97	33	72	43	48
4	131	14	106	24	97	34	69	44	47
5	128	15	104	25	95	35	66	45	47
6	125	16	100	26	92	36	63	46	46
7	123	17	97	27	90	37	60	47	46
8	122	18	97	28	85	38	57	48	45
9	119	19	95	29	85	39	54	49	45
10	117	20	95	30	81	40	51	50	45

There are thirty-five cases reported of velocities exceeding fifty miles per hour, one of them amounting to seventy-one miles per hour, viz., Yankton, May 29.1, 1873. These observations do not indicate any increase in the gradient above that corresponding to a velocity of fifty miles per hour. This fact seems to indicate that these very high velocities are local and are due to a local cause. The barometric gradient is a very reliable indication of the average velocity of the wind over a large area: but over a small area there may be exceptional velocities which do not sensibly affect the barometric gradient as determined from observations at stations distant 100 miles from each other. Such exceptional velocities may result from a strong upward movement of the air in the neighborhood of the station of observation.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

ART. II.—*Notices of Recent American Earthquakes.* No. 7; by Professor C. G. ROCKWOOD, Jr., College of New Jersey.

IN the following notices, those based upon *single* newspaper reports, and which could not be otherwise verified, are printed in smaller type, and the source of the information is indicated.

For information received I am indebted to John M. Batchelder of Boston, Fred. E. Goodrich of the Boston Post, Principal J. W. Dawson of Montreal, Professor E. T. Quimby of Dartmouth College and others.

1876.—May 10. A shock at Santa Barbara, Cal.—(U. S. Sign. Serv.)

Aug. 16. At 1.15 P. M. The bark Forest Queen experienced a heavy shock of fifteen seconds duration in lat. 41° 55′ N., long. 126° 25′ W., off the southern part of Oregon.—(U. S. Sign. Serv.)

Aug. 16. At 11.25 P. M., at Lower Brule Indian Agency, Dakota T., a shock of seven seconds duration with loud rumbling noise.—(U. S. Sign. Serv.)

Sept. 21. A shock about 11.30 P. M., felt at Newport, R. I. and at Fall River and New Bedford, Mass., and adjacent places. At Fort Adams, R. I., it was reported to be "apparently from east to west and lasting about ten seconds."

Sept. 25. Two distinct and heavy shocks with an interval of about fifteen minutes between them were felt about midnight of 24th and 25th throughout southern Illinois and Indiana, from St. Louis, Mo. to Indianapolis, Ind., and Louisville, Ky. They appear to have been most severe in the valley of the Wabash River, from Mt. Carmel and Friendsville, Ill., to Evansville, Ind. The time given for the second and heavier shock varied from 12 midnight to 12.15 A. M.

Sept. 26. A slight shock reported at Friendsville, Ill.—(U. S. Sign. Serv.)

Oct. 6. Two shocks at San Francisco at 9.20 and 10.08 P. M. The first and heavier, lasting ten seconds, with a motion from N. W. to S. E. was felt also at Oakland, San José and Angel Island.

Nov. 20. A shock at Eastport, Me., at 1 P. M.—(U. S. Sign. Serv.)

Dec. 11. About 7 P. M. at Silver Mountain, Cal., a series of seven shocks were felt within a period of thirty minutes, the first and third shocks being heavier than the others. They were preceded by a rumbling noise and apparently came from the south or southeast.

A slight shock was also reported at 3 o'clock next morning at the same place.

Dec. 12. A slight shock in the City of Charleston, S. C., in the evening.—(U. S. Sign. Serv.)

Dec. 21. A shock at Wytheville, Va., at 10.30 A. M.—(U. S. Sign. Serv.)

1877.—Jan. 10. A slight shock about 1.15 P. M. at Los Angeles, Cal., which at Benedict Cañon near there, was felt as three distinct shocks preceded by a loud report.—(Los Angeles Express, in N. Y. Times.)

Jan. 13. A heavy earthquake about noon, forty-five miles southeast of San Diego, Cal. "The reverberations were from east to west, and extended throughout the mountains to the borders of Cajou Valley."—(N. Y. Times.)

Feb. 17. A heavy shock at Quincy, Plumas Co., Cal., in the morning.

Feb. 18. A distinct shock at 2.20 P. M. at Portland, Me., with rumbling sound.

Feb. 24. The Honolulu Gazette of Feb. 28th reports a submarine volcanic outbreak in Kealakeakaua Bay at 3 A. M., Feb. 24. During the same night a severe earthquake was felt at Koawalsa and Kell.

March 8. Two light shocks about 2 A. M., and a few minutes before 5 A. M. at Helena, Montana.—(Helena Independent, in N. Y. Times.)

March 19. A shock at Kingston, Jamaica, at 12.55 A. M.

April 17. A slight shock of short duration at Panama at 5.50 A. M.—(U. S. Sign. Serv.)

April 23. A slight shock at Auburn, N. H., at 11 A. M., from N. W. to S. E.—(U. S. Sign. Serv.)

April 26. A slight shock at Franklin, N. C., at 5 P. M.—(U. S. Sign. Serv.)

May 2. A shock "lasting eight or ten seconds" at 10.20 P. M. at Oshawa, Ontario.

May 9. At 8.30 P. M., a series of severe shocks, lasting four or five minutes, and followed by a destructive tidal wave, were felt on the coast of Peru, Bolivia and Chili. The center of disturbance appeared to be the neighborhood of the volcano Ilaga, on the borders of Peru and Bolivia, in lat. 21° S. The shocks were felt along the coast from beyond Arequipa, Peru, to Valparaiso, Chili, but were most violent and destructive from Iquique, where the duration was 4 m. 20 sec., to Cobija, Mexillones and Chavanago, Bolivia. The disturbance does not appear to have extended very far inland. The sea wave however spread over the entire Pacific, being felt along the coast of Mexico and California (whence it was reported by the signal service a day before news of the shock was received), at the Sandwich Islands, the Marquesas Islands, Japan and Australia. On the Peruvian and Bolivian coasts the wave was from twenty to sixty feet high and caused great destruction of life and property, both on land and among the shipping in the harbors. At the Sandwich Islands the wave was fifteen to thirty-six feet high, and on the Australian coast one to six feet high. Its average rate of progress, as calculated from the time of arrival of the first wave, and assuming its origin to have been near Iquique, was as follows:—to Callao 228 miles per hour, to San Francisco 348 miles, to Honolulu 408 miles and to Australia 378 miles per hour.

On the Peruvian coast lighter shocks continued at intervals for some days, and later reports indicate that the whole coast has suffered a considerable permanent upheaval.

At San José, Costa Rica, a feeble shock was felt at 5.28 A. M. of the 10th (local time) or 9^h 54^m after the shock at Iquique.

In the Sandwich Islands the volcano of Kilauea exhibited

unusual activity, and eruptions of lava with occasional earthquake shocks occurred during the week preceding the tidal wave, especially one at 2.45 P M., May 4th.

More detailed local reports of the phenomena may be found in this Journal, III, xiv, p. 77, U. S. Weather Review, May, 1877, Scientific American, vol. xxxvii, pp. 3, 345, Nature, vol. xvi, pp. 112, 174, 198.

May 11. A slight shock in the afternoon in Schenectady and Schoharie Counties, N. Y.

May 14. A severe shock at Lima and Callao, lasting twenty-two seconds.

May 15. From Port Stanley, Ont., it is reported that a wave five feet high, apparently due to some earthquake shock, swept along the northern shore of Lake Erie, followed for an hour by smaller ones.

May 25. A shock at Knoxville, Tenn.—(U. S. Sign. Serv.)

May 26. A shock at 3 P. M. at New Harmony, Ind.—(U. S. Sign. Serv.

May 30. A heavy shock between 2 and 3 A. M., at Pasa Robles, Cal.

June 11. A volcanic eruption, smoke and boulders, in the mountains near Flowing Wells Station, Southern Pacific R. R., about sixty miles from Yuma, preceded by a violent vibration of the earth.

June 18. At Milwaukee, Wis., at 7.30 P. M., the water in Lake Michigan fell two feet in half an hour and rose again more quickly.—(U. S. Sign. Serv.)

June 23. A shock about 11.30 P. M. at Bakersfield, Cal. "It seemed to be in the nature of an upheaval rather than vibratory."

July 9. A shock at Sacramento, Cal., lasting one minute. Oscillations, E. and W.—(U. S. Sign. Serv.)

July 14. Two shocks at 6.40 P. M., at Memphis, Tenn., lasting several seconds, vibrations from S. W. or W. to N. E. or E.

July 15. Three shocks apparently from the west, and lasting five seconds, at Carbondale, Ill.—(U. S. Sign. Serv.)

July 17. A sharp shock at 3 A. M., lasting about thirty seconds, at River du Loup, Canada.

Aug. 10. A shock lasting several seconds at Florence, N. J.—(U. S. Sign. Serv.)

Aug. 17. A slight shock about 11 A. M., felt in Detroit, Mich., and a few neighboring towns. It lasted from thirty seconds to one minute, and was accompanied by a rumbling sound.

———. At 7.30 P. M. of the same day a heavy shock, lasting fifteen seconds, was felt at Campo, Cal.—(U. S. Sign. Serv.)

Aug. 23. Shocks of an alarming nature were felt at Cobija, Bolivia, at 1.40 P. M., and at Iquique at 5 P. M., and a few days earlier at Copiapo, Chili.

Sept. 1. A slight shock at 11 A. M. at Latonsville, Sandy Springs, Brookville, Laurel and other points in Prince George's Co., Md.

Sept. 7. A shock at 10 P. M. at Yuma, Arizona.—(U. S. Sign. Serv.)

Sept. 10. A shock at 9.59 A. M., felt in the valley of the Delaware River from Trenton to Philadelphia. It affected an extent of country, about thirty-five miles along the river by twenty miles wide, and having its center at Burlington, N. J. It lasted thirty or forty seconds, had an apparent motion toward the southwest, and was accompanied by a rumbling noise.

Sept. 18. Panama advices of this date say, shocks of earthquake were continuously felt in some of the southern ports of Peru.

Sept. 29. A shock at Campo, Cal., at 2.30 P. M., lasting five seconds, with low rumbling.—(U. S. Sign. Serv.)

Oct. 9. A severe shock at 2.20 A. M. at Lima and Callao, Peru; felt also in Pisco, Ica and Chincha, where two shocks were reported. The vibration was from north to south.

Oct. 12. Quite severe shocks were felt in Oregon, occurring in Portland at 1.53 P. M., two shocks being noticed; at Marshfield, Clackamas Co., at 1.45 P. M.; and at Cascades at 1.52 P. M. (Another shock was felt at Cascades at 9 A. M.) The vibrations were in each case from north to south and were sufficiently violent to overthrow chimneys.

———. At 3.26 A. M. of the same day a slight earthquake was felt on the Isthmus of Panama.

Oct. 26. Between 5 and 6 P. M. the schooner Leo felt a severe earthquake shock, continuing about ten seconds, in lat. 43° 13′ N., long 128° W., the vessel being 300 or 400 miles from the coast of Oregon.

Nov. 4. About 2 A. M. a rather severe earthquake was felt throughout a large part of Canada, New York and New England. It was reported from Ottawa, Perth and many other places in Ontario, east of a line joining Kingston and Pembroke; from Cornwall, Montreal and other places in the St. Lawrence Valley as far east as Three Rivers; from Hanover, N. H., Springfield, Mass., Hartford, Conn., and other places along the Connecticut River; from Burlington and Bennington, Vt., Plattsburg, Whitehall and Saratoga, N. Y., and the valley

of Lake Champlain and the Hudson as far south as Albany; and finally from Utica, Rome, Auburn and the Mohawk Valley. It was probably felt throughout the whole Adirondack region which is thus enclosed, but whence no reports could be expected. It would thus seem to have been felt over an irregular trapezium, whose angles are marked by Pembroke, Ont., Three Rivers, P. Q., Hartford, Conn., and Auburn, N. Y.; and which is therefore some 200 miles on its northern and southern sides, about 300 on the east and 175 on the west. In regard to the exact time of the shock the reports differ too much among themselves, and are mostly of too vague a nature to permit any deductions therefrom as to the direction or rate of progress of the vibration. Comparing the reports from thirty-six localities in which the time is given, and rejecting three as quite wide of the truth, we find them cluster closely about 2 A. M., none earlier than 1.45, none later than 2.10, most being between 1.50 and 2, local time. The only ones, however, which appear to be reliably accurate are Montreal 1.50 A. M. (J. W. Dawson), Hartford 1.56 (Ed. Hartford Courant)=1.52 Montreal time, and Dudley observatory, Albany, 1.53 = 1.54 Montreal time. The Hartford record is also confirmed by an apparently careful report from Windsor, Conn., giving 1.55 A. M. Many (25) reports give in a general way "2 A. M.," "about 2 A. M.," etc. The duration in Montreal was about twenty seconds. The other reports of its duration vary from four or five seconds to two or three minutes and in one case five minutes. Most of them however give about half a minute. It seems to have been most severe in the valley of the St. Lawrence and about Lake Champlain, where the vibration was sufficient to overturn crockery, crack ceilings and in a few cases to throw down chimneys. The reports are nearly unanimous that the vibration advanced from west to east, only one report (Hanover, N. H.) stating it as from north to south, this however on the concurrent testimony of three observers. In some places a rumbling noise and in others two or several shocks were reported; at Dudley observatory "a severe shock of ten seconds duration, followed after an interval of thirty seconds by a lighter one;" at Hanover, "a succession of five or six waves, increasing in intensity for the first third of the time and then decreasing;" in Montreal "a low rumbling sound followed by a sharp explosion and then a tremor."

In compiling the above I have been able to compare reports from fifty-eight stations.

Nov. 14. A slight shock at 9.40 A. M. at Cornwall, Ont.

Nov. 15. About noon several shocks were felt in Iowa and adjoining portions of Kansas, Nebraska and Dakota. The times given were: Iowa City 12.30 P. M., Council Bluffs 12.15,

movement E. to W., Omaha 11.40 A. M., three shocks lasting ten seconds, Topeka and Atchison, Ks., 12 M., and Yankton, D. T., 11.30 A. M.

These times are plainly discordant, but at this distance no data are available for correcting them.

Nov. 16. A slight shock about 2.20 A. M. at Knoxville, Tenn.

Nov. 18. A shock about 5 A. M. in the Bermuda Islands — (Newark Daily Advertiser).

Princeton, N. J., Nov. 30, 1877.

ART. III.—*Observations on under-water Oceanic Temperature;* by Captain G. E. BELKNAP, U. S. Navy.

[When, many years ago, it was announced by Lieutenant Maury and others, that a cold stratum might exist in the ocean between two adjacent warmer ones, or *vice versa* and that there might be a succession of such conditions between the surface and the bottom, the assertion was believed by many to be fallacious and contrary to the laws of ocean physics, and that warm water would necessarily rise until it was above that of a lower temperature. More recently, however, reliable observations of the northern seas have established this fact, the Germans, the Swedes and the Norwegians having severally verified it. The investigations of Professor Hind on the coast of Labrador, have shown many cases of a similar character. A similar observation was made by Captain Belknap, of the U. S. Navy, while in command of the U. S. steamer Tuscarora, during her famed cruise in the Pacific; and by the courtesy of Commodore Ammen, chief of the Bureau of Navigation, we are permitted to present an abstract of a report made by that officer on the 2d of September, 1874.—EDS.]

A STUDY of the surface and under-surface temperatures, in the Pacific Ocean, has yielded some interesting results. Great care was taken to make the observations as accurate as possible, and the surface temperatures are invariably means of four and five thermometers. Whenever there was any doubt, or any marked change in temperature, the observations were always repeated. In taking the under-surface temperature along the Kurile Islands, the indications of the Miller-Casella thermometers were sometimes so startling and perplexing, the indicated temperatures being so low, that the observations were often duplicated to verify their accuracy; if the second observation confirmed the first, the results were accepted as true; otherwise they were rejected.

Proceeding in this way, a cold stratum between two warm strata, was found to exist quite near the surface, between the

parallels of 49° and 52° north latitude and the meridians of 158° and 167° east longitude. The upper part of the stratum in one place, showing a temperature of 33°·7 F., was only 20 fathoms below the surface, while at 10 fathoms below the surface the temperature was 41° F. At a depth of 100 fathoms the temperature was 32° F.; below that curve to a depth of 200 fathoms, the range of temperature was from 34°·5 F. to 38°·7 F. The width of the cold stratum gradually narrowed to a point in an easterly direction from the coast, or as the edge of the Japan stream was approached.

I may say here that the indications of the Miller-Casella thermometers are not always reliable, as the needles sometimes jump in the tubes, and this was especially the case on this northern line, where the changes of under-surface temperatures are so much more sudden than in the Central North Pacific where serial temperatures were taken by this ship.

In three or four instances, the thermometers came up from the bottom and intermediate depths, indicating temperatures of from 20° F. to 28° F.; temperatures manifestly impossible.

There can be no doubt, however, of the existence of the cold stratum described above, as no temperature was recorded until repeated observations with different thermometers confirmed its accuracy.

An inspection of the surface-temperature chart will show that the coldest surface water was found along the Kurile Islands, between the parallels of 45° and 47° north latitude. The temperature of the air was also lower in that region than at any point further north, and the lowest snow line was observed there, though the range of latitude traversed was nearly eight degrees higher. The current in that locality was found to be setting in a southerly direction, and undoubtedly pouring out of the Sea of Ochotsk.

The surface temperatures along the Aleutian Islands show considerable variation, both in the Pacific and in Behring's Sea, doubtless attributable to tidal influences, the direction of the wind, and the meeting of different currents.

In passing from Behring's Sea to the Pacific, through Onnimak Pass, on the morning of the 17th of August, the surface temperature rose seven degrees in one hour, some five to seven miles inside of the Pass, the current at the time setting with moderate strength into the sea.

The lowest surface temperature along the Kurile group was 36°·4 F.; along the Aleutian Islands the surface temperatures ranged from 41°·6 F. to 49° F. and along the continuation of the line, across the Gulf of Alaska, to Cape Flattery, the range of temperature was found to be from 50° F. to 59° F., indicating in the most unmistakable manner the influence of that

branch of the Japan stream which, curving to the northward near the meridian of 140° west longitude, impinges upon the coasts of Alaska, and following the line of the shore bordering on the Gulf of Alaska, sweeps back to the westward and southwestward to the Aleutain chain; for the moment Onnimak Pass is cleared, the temperature of the water rises, and the current is found to be setting to the southwestward.

The following table will show some of the differences of temperature observed on the line sounded from Honolulu to the Bonin Islands, and that part of the northern line from the southern point of Kamtchatka to Onnimak Pass in Behring's Sea:

	Southern Line, Central North Pacific.		Northern Line, North Pacific and Behring's Sea.	
Surface,	70° to 76° F.		36°·4 to 49° F.	
Under Surface	30 f'ms,	70°·8	73°·5	31°·5	41°·9
"	50 "	63°·5	72°·7	31°·9	39°·7
"	100 "	62°	70°	31°·1	38°·5
"	200 "	48°·5	58°·7	34°·3	37°·9
"	300 "	41°·4	50°·3	34°·4	37°·3
"	500 "	38°·9	40°·6	34°·8	35°·9
"	1000 "	35°·5		33°·5	33°·8
"	2000 "	33°·2	33°·9	33°·5	33°·8
"	3000 "	33°·2	33° 9	33°·1	33°·3

The very low temperatures noted at the depth of 30 fathoms to 206 fathoms are some of those observed in the cold stratum already described in this report.

The serial temperatures observed on this northern line were not so extended as could have been wished, owing to the loss and breakage of thermometers and to the fact that two of the instruments furnished had to be thrown aside as worthless. In the latter case the mercury would crowd up past the needle, rendering the indications valueless, and that defect in those instruments could not be overcome.

The thermometers sent down at the 3,664 fathom cast came up unharmed, and as some of the "Challenger's" instruments broke at a depth of 3,875 fathoms the maximum pressure which the Miller-Casella thermometers will bear must be somewhere between those depths, or a pressure of about four and three-fourths tons per square inch.* The temperature indicated at 3,664 fathoms is 33°·8 F.

I should take into consideration, however, the fact that using hempen line and time intervals for sounding, that the depths found by the "Challenger" were not so accurate as those obtained by the "Tuscarora" with piano wire and dynamometer.

* From later results obtained by the Challenger this deduction is probably incorrect, as I believe she received whole thermometers back on one or two occasions from a depth of over 4,000 fathoms.

ART. IV.—*On the Magnetic Effect of Electric Convection;** by HENRY A. ROWLAND of the Johns Hopkins University, Baltimore.

THE experiments described in this paper were made with a view of determining whether or not an electrified body in motion produces magnetic effects. There seems to be no theoretical ground upon which we can settle the question, seeing that the magnetic action of a conducted electric current may be ascribed to some mutual action between the conductor and the current. Hence an experiment is of value. Professor Maxwell, in his "Treatise on Electricity," Art. 770, has computed the magnetic action of a moving electrified surface, but that the action exists has not yet been proved experimentally or theoretically.

The apparatus employed consisted of a vulcanite disc 21·1 centimeters in diameter and ·5 centimeter thick which could be made to revolve around a vertical axis with a velocity of 61· turns per second. On either side of the disc at a distance of ·6 cm. were fixed glass plates having a diameter of 38·9 cm. and a hole in the center of 7·8 cm. The vulcanite disc was gilded on both sides and the glass plates had an annular ring of gilt on one side, the outside and inside diameters being 24·0 cm. and 8·9 cm. respectively. The gilt sides could be turned toward or from the revolving disc but were usually turned toward it so that the problem might be calculated more readily and there should be no uncertainty as to the electrification. The outside plates were usually connected with the earth; and the inside disc with an electric battery, by means of a point which approached within one-third of a millimeter of the edge and turned toward it. As the edge was broad, the point would not discharge unless there was a difference of potential between it and the edge. Between the electric battery and the disc, a commutator was placed, so that the potential of the latter could be made plus or minus at will. All parts of the apparatus were of non-magnetic material.

Over the surface of the disc was suspended, from a bracket in the wall, an extremely delicate astatic needle, protected from electric action and currents of air by a brass tube. The two needles were 1·5 cm. long and their centers 17·98 cm. distant from each other. The readings were by a telescope and scale. The opening in the tube for observing the mirror was protected

* The experiments described were made in the laboratory of the Berlin University through the kindness of Professor Helmholtz, to whose advice they are greatly indebted for their completeness. The idea of the experiment first occurred to me in 1868 and was recorded in a note book of that date.

from electrical action by a metallic cone, the mirror being at its vertex. So perfectly was this accomplished that no effect of electrical action was apparent either on charging the battery or reversing the electrification of the disc. The needles were so far apart that any action of the disc would be many fold greater on the lower needle than the upper. The direction of the needles was that of the motion of the disc directly below them, that is, perpendicular to the radius drawn from the axis to the needle. As the support of the needle was the wall of the laboratory and revolving disc was on a table beneath it, the needle was reasonably free from vibration.

In the first experiments with this apparatus no effect was observed other than a constant deflection which was reversed with the direction of the motion. This was finally traced to the magnetism of rotation of the axis and was afterward greatly reduced by turning down the axis to ·9 cm. diameter. On now rendering the needle more sensitive and taking several other precautions a distinct effect was observed of several millimeters on reversing the electrification and it was separated from the effect of magnetism of rotation by keeping the motion constant and reversing the electrification. As the effect of the magnetism of rotation was several times that of the moving electricity, and the needle was so extremely sensitive, numerical results were extremely hard to be obtained, and it is only after weeks of trial that reasonably accurate results have been obtained. But the qualitative effect, after once being obtained, never failed. In hundreds of observations extending over many weeks, the needle always answered to a change of electrification of the disc. Also on raising the potential above zero the action was the reverse of that when it was lowered below. The *swing* of the needle on reversing the electrification was about 10· or 15· millimeters and therefore the point of equilibrium was altered 5 or 7½ millimeters. This quantity varied with the electrification, the velocity of motion, the sensitiveness of the needle, etc.

The direction of the action may be thus defined. Calling the motion of the disc + when it moved like the hands of a watch laid on the table with its face up, we have the following, the needles being over one side of the disc with the north pole pointing in the direction of positive motion. The motion being +, on electrifying the disc + the north pole moved toward the axis, and on changing the electrification, the north pole moved away from the axis. With − motion and + electrification, the north pole moved away from the axis, and with − electrification, it moved toward the axis. The direction is therefore that in which we should expect it to be.

To prevent any suspicion of currents in the gilded surfaces,

the latter, in many experiments, were divided into small portions by radial scratches, so that no tangential currents could take place without sufficient difference of potential to produce sparks. But to be perfectly certain, the gilded disc was replaced by a plane thin glass plate which could be electrified by points on one side, a gilder induction plate at zero potential being on the other. With this arrangement, effects in the same direction as before were obtained, but smaller in quantity, seeing that only one side of the plate could be electrified.

The inductor plates were now removed, leaving the disc perfectly free, and the latter was once more gilded with a continuous gold surface, having only an opening around the axis of 3·5 cm. The gilding of the disc was connected with the axis and so was at a potential of zero. On one side of the plate, two small inductors formed of pieces of tin-foil on glass plates, were supported, having the disc between them. On electrifying these, the disc at the points opposite them was electrified by induction but there could be no electrification except at points near the inductors. On now revolving the disc, if the inductors were very small, the electricity would remain nearly at rest and the plate would as it were revolve through it. Hence in this case we should have conduction without motion of electricity, while in the first experiment we had motion without conduction. I have used the term "nearly at rest" in the above, for the following reasons. As the disc revolves the electricity is being constantly conducted in the plate so as to retain its position. Now the function which expresses the potential producing these currents and its differential coefficients must be continuous throughout the disc, and so these currents must pervade the whole disc.

To calculate these currents we have two ways. Either we can consider the electricity at rest and the motion of the disc through it to produce an electromotive force in the direction of motion and proportional to the velocity of motion, to the electrification, and to the surface resistance; or, as Professor Helmholtz has suggested, we can consider the electricity to move with the disc and as it comes to the edge of the inductor to be set free to return by conduction currents to the other edge of the inductor so as to supply the loss there. The problem is capable of solution in the case of a disc without a hole in the center but the results are too complicated to be of much use. Hence scratches were made on the disc in concentric circles about ·6 cm. apart by which the radial component of the currents was destroyed and the problem became easily calculable.

For, let the inductor cover $\frac{1}{n}$ the part of the circumference of any one of the conducting circles; then, if C is a constant,

the current in the circle outside the inductor will be $+\frac{C}{n}$, and inside the area of the inductor $-C\frac{(n-1)}{n}$. On the latter is superposed the convection current equal to $+C$. Hence the motion of electricity throughout the whole circle is $\frac{1}{n}$, what it would have been had the inductor covered the whole circle.

In one experiment n was about 8. By comparison with the other experiments we know that had electric conduction alone produced effect we should have observed at the telescope $-5\cdot$ mil. Had electric convection alone produced magnetic effect we should have had $+5\cdot7$ mil. And if they both had effect it would have been $+\cdot7$ mil., which is practically zero in the presence of so many disturbing causes. No effect was discovered, or at least no *certain* effect, though every care was used. Hence we may conclude with reasonable certainty that electricity produces nearly if not quite the same magnetic effect in the case of convection as of conduction, provided the same quantity of electricity passes a given point in the convection stream as in the conduction stream.

The currents in the disc were actually detected by using inductors covering half the plate and placing the needle over the uncovered portion; but the effect was too small to be measured accurately. To prove this more thoroughly numerical results were attempted, and, after weeks of labor, obtained. I give below the last results which, from the precautions taken and the increase of experience, have the greatest weight.

The magnetizing force of the disc was obtained from the deflection of the astatic needle as follows. Turning the two needles with poles in the same direction and observing the number n of vibrations, and then turning them opposite and finding the number n' of vibrations in that position, we shall find, when the lower needle is the strongest,

$$X-X'\frac{n^2-n'^2}{n^2+n'^2}=\frac{n'^2}{n^2+n'^2}\frac{\Delta}{D}H. \qquad (1)$$

Where X' and X are the forces on the upper and lower needle respectively, Δ the deflection, D the distance of the scale and H the horizontal component of the earth's magnetism. As X' and n' are very small the first term is nearly $X-X'$. The torsion of the silk fiber was too small to affect the result, or at least was almost eliminated by the method of experiment.

The electricity was in the first experiment distributed nearly uniformly over the disc with the exception of the opening in the center and the excess of distribution on the edge. The surface density on either side was

$$\sigma = \frac{V - V'}{2\pi(B-\beta)}. \tag{2}$$

$V-V'$ being the difference of potential between the disc and the outside plates, β the thickness of the disc and B the whole distance apart of the outside plates. The excess on the edge was (Maxwell's Electricity, Art. 196, Eq. 18),

$$E = 2(V-V')\frac{BC}{\pi(B-\beta)}\log_\varepsilon\left(2\cos\frac{\pi\beta}{2B}\right), \tag{3}$$

where C is the radius of the disc.

We may calculate the magnetic effect on the supposition that, as in the conducted current, the magnetizing force due to any element of surface is proportional to the quantity of electricity passing that element in a unit of time. The magnetic effect due to the uniform distribution has the greatest effect. With an error of only a small fraction of a per cent, we may consider the two sides of the disc to coincide in the center. Taking the origin of coördinates at the point of the disc under the needle and the center of the disc on the axis of X we find for both sides of the disc, the radial component of the force parallel to the disc,

$$X = \frac{8\pi N\sigma a}{v}\int_{-(C+b)}^{C-b}\int_0^{v'}\frac{(b+x)\,dx\,dy}{(a^2+x^2+y^2)^{\frac{3}{2}}} =$$

$$\frac{8\pi N\sigma a}{v}\int_{-(C+b)}^{C-b}\frac{(b+x)\sqrt{C^2-(b+x)^2}}{(a^2+x^2)\sqrt{a^2+C^2-b^2-2bx}},$$

where a is the distance of the needle from the disc and b that from the axis; N is the number of revolutions of the disc per second and $v=28{,}800{,}000{,}000$ centimeters per second according to Maxwell's determination. The above integral can be obtained exactly by elliptic integrals, but as it introduces a great variety of complete and incomplete elliptic integrals of all three orders, we shall do best by expanding as follows:

$$X = \frac{4\pi N\sigma}{v}P = \frac{4\pi N\sigma}{v}(A_1+A_2+A_3+\text{ \&c.}), \tag{4}$$

$$A_1 = 2b\left(\text{arc tan}\frac{C-b}{a}+\text{arc tan}\frac{C+b}{a}\right) - a\log_\varepsilon\frac{M}{N},$$

$$A_2 = -\frac{a}{2b}\left((s+b)\log_\varepsilon\frac{M}{N}-2C\right),$$

$$A_3 = \frac{a}{16b^2}\left\{-4Cs+(3s^2+2sb+a^2)\log_\varepsilon\frac{M}{N}\right.$$

$$\left.+\left(5s^3+3s^2b+a^2(s+b)\right)\frac{4Cb}{MN}\right\}\text{ \&c., \&c.,}$$

where $s=\dfrac{a^2+C^2-b^2}{2b}$, $M=a^2+(C+b)^2$, $N=a^2+(C-b)^2$.

From this must be subtracted the effect of the opening in the center, for which the same formula will apply.

The magnetic action of the excess at the edge may be calculated on the supposition that that excess is concentrated in a circle of a little smaller diameter, C′, than the disc;

$$\text{therefore,}\quad X_1=\frac{NE}{v}\frac{ak}{2b\sqrt{C'b}}\left\{\frac{2-k^2}{1-k^2}E(k)-F(k)\right\}, \qquad (5)$$

where $k=\frac{2\sqrt{C'b}}{\sqrt{a^2+(C'+b)^2}}$, and $F(k)$ and $E(k)$ are complete elliptic integrals of the second and first orders respectively.

The determination of the potential was by means of the spark which Thomson has experimented on in absolute measure. For sparks of length l between two surfaces nearly plane, we have on the centimeter, gram, second system, from Thomson's experiments,

$$V-V'=117{\cdot}5(l+{\cdot}0135),$$

and for two balls of finite radius, we find, by considering the distribution on the two sheets of an hyperboloid of revolution,

$$V-V'=117{\cdot}5\,(l+{\cdot}0135)\frac{r}{2\sqrt{r+1}}\log\frac{\sqrt{r+1}+1}{\sqrt{r+1}-1},$$

where r is the ratio of the length of spark to diameter of balls and had in these experiments a value of about 8. In this case

$$V-V'=109{\cdot}6\,(l+{\cdot}0135). \qquad (6)$$

A battery of nine large jars, each 48· c. m. high, contained the store of electricity supplied to the disc, and the difference of potential was determined before and after the experiment by charging a small jar and testing its length of spark. Two determinations were made before and two after each experiment, and the mean taken as representing the potential during the experiment.

The velocity of the disc was kept constant by observing a governor. The number of revolutions was the same, nearly, as determined by the sizes of the pulleys or the sound of a Seebeck siren attached to the axis of the disc; the secret of this agreement was that the driving cords were well supplied with rosin. The number of revolutions was 61· per second.

In such a delicate experiment, the disturbing causes, such as the changes of the earth's magnetism, the changing temperature of the room, &c., were so numerous that only on few days could numerical results be obtained, and even then the accuracy could not be great. The centimeter, gram, second system, was used.

First Series. $a=2{\cdot}05$, $b=9{\cdot}08$, $n={\cdot}697$, $D=110$·, $H-{\cdot}182$ nearly, $B=1{\cdot}68$, $\beta={\cdot}50$, $C=10\,55$, $N-61$·, $v=28{,}800{,}000{,}000$·, $n'={\cdot}0533$, $C'=10$.

Direction of motion.	Electrification of disc.	Scale reading in mm.	Deflection on reversing electrificat'n in mm.	Length of spark.
+	−	99·	7·25	·295
	+	107·5		
	−	101·5		
−	+	68·5	8·25	·290
	−	76·5		
	+	68·0		
+	+	97·	7·00	·282
	−	91·5		
	+	100·		
−	+	59·	6·75	·265
	−	65·5		
	+	58·5		
+	+	92·5	6·75	·290
	−	85·		
	+	91·0		
−	+	52·5	5·50	·285
	−	57·5		
	+	51·5		
+	+	82·0	5·85	·285
	−	76·0		
	+	81·7		
−	+	36·5	6·50	·275
	−	43·0		
	+	36·5		
+	+	68·0	7·00	·290
	−	61·0		
	+	68·0		
−	+	27·5	6·50	·288
	−	33·5		
	+	26·5		
Mean values.			6·735	·2845

Hence, $\Delta = \frac{\cdot 6735}{2} = \cdot 337$ and $l = \cdot 2845$.

From equation (1),

$$X - \cdot 99\, X' = \frac{1}{305700\cdot} = 00000327.$$

By calculation from the electrification we find

$$X - \cdot 99\, X' = \frac{1}{296800\cdot} = \cdot 00000337.$$

The effect on the upper needle, X′, was about $\frac{1}{5}\frac{1}{0}$ of that on the lower X.

Second Series. Everything the same as before except the following. $b = 7\cdot 65$, $n' = \cdot 0525$.

Direction of motion.	Electrification of disc.	Scale reading in mm.	Deflection on reversing electrificat'n in mm.	Length of spark.
+	+	172·5	7·0	·300
	−	165·5		
	+	172·5		
−	+	120·0	7·5	·295
	−	127·5		
	+	121·5		
	−	129·0		
+	−	163·5	7·25	·297
	+	170·5		
	−	163·0		
	+	170·5		
−	+	118·0	8·25	·270
	−	127·0		
	+	120·0		
	−	127·5		
Mean values.			7·50	·2955

$$\therefore \quad \Delta = \cdot 375, \qquad l = \cdot 2955.$$

Hence for this case we have from equation (1),

$$X - \cdot 99\, X' = \frac{1}{315000 \cdot} = \cdot 00000317.$$

And from the electrification,

$$X - \cdot 99\, X' = \frac{1}{286000 \cdot} = \cdot 00000349.$$

Third Series. Everything the same as in the first series, except $b = 8 \cdot 1$, $n' = \cdot 0521$, $D = 114$.

Direction of motion.	Electrification of disc.	Scale reading in mm.	Deflection on reversing electrificat'n in mm.	Length of spark.
−	+	151·0	7·50	·287
	−	158·5		
	+	151·0		
+	+	192·0	7·25	·292
	−	185·5		
	+	193·5		
−	−	157·5	8·25	·295
	+	148·5		
	−	157·5		
	+	150·0		
+	−	185·0	7·75	·302
	+	192·5		
	−	185·5		
	+	193·5		
−	−	151·0	7·25	·287
	+	143·5		
	−	150·5		
Mean values.			7·60	·2926

$$\therefore \quad \Delta = \cdot 380, \qquad l = \cdot 2926.$$

For this case from equation (1)

$$X - \cdot 99\, X' = \frac{1}{295000\cdot} = \cdot 00000339,$$

and from the electrification

$$X - \cdot 99\, X' = \frac{1}{281500\cdot} = \cdot 00000355.$$

The error amounts to 3, 10 and 4 per cent respectively in the three series. Had we taken Weber's value of v the agreement would have been still nearer. Considering the difficulty of the experiment and the many sources of error, we may consider the agreement very satisfactory. The force measured is, we observe, about $\frac{1}{50000\cdot}$ of the horizontal force of the earth's magnetism.

The difference of readings with + and − motion is due to the magnetism of rotation of the brass axis. This action is eliminated from the result.

It will be observed that this method gives a determination of v, the ratio of the electromagnetic to the electrostatic system of units, and if carried out on a large scale with perfect instruments might give good results. The value $v = 300{,}000{,}000\cdot$ meters per second satisfies the first and last series of the experiments the best.

Berlin, February 15th, 1876.

ART. V.—*Notes of Observations on Jupiter and its Satellites;* by MARIA MITCHELL.

THE following observations were made at the observatory of Vassar College; longitude $4^h\ 55^m\ 33^s$, latitude 41° 41′ 18″. The instrument used was the Equatorial telescope; the power usually 230.

1874, May 2.—Observations on Jupiter began at $10^h\ 18^m$. The seeing was excellent. With a power of 600 the ruddiness of the equatorial belt was brought out; two large dark spots on its upper portion were very striking in appearance, the intercepted space between them being conspicuously white. The shadow of the 4th satellite was near egress. It touched the limit of the planet, in internal contact at $10^h\ 37^m\ 10^s\cdot 3$, and was last seen at $11^h\ 2^m\ 45^s\cdot 8$. At times during the hour I thought the shadow was followed by a companion shadow.

1874, May 3.—The 3d satellite of Jupiter was occulted at $9^h\ 11^m\ 2^s\cdot 5$. [This observation is by Miss Fisher (student) with a small telescope.]

1874, May 7.—The ingress of the 1st satellite of Jupiter was observed. The satellite was in external contact at $10^h\ 50^m\ 39^s$. The internal contact was at $10^h\ 55^m\ 7^s$.

1874, May 14.—Observations on Jupiter began at 8 P. M. The broad equatorial belt was rosy and was seen fully out to the following limb. The shadow of the 3d satellite was upon the disc. The shadow was dark but not black. I could not call it circular; the longer diameter was nearly parallel with the equatorial belt. It left the planet's disc at $10^h\ 1^m\ 11^s{\cdot}1$.

1874, May 19.—The noticeable peculiarity of the planet's disc is that of a large white spot on the broad belt near the center at $8^h\ 10^m$ P. M. At $9^h\ 45^m$ no trace of this spot could be found, although the equatorial belt was seen out to the preceding limb.

1874, May 22.—There was a very decided change in the spots from dark to light between $9^h\ 6^m$ P. M. and $9^h\ 35^m$ P. M.

1874, May 28.—The planet was unusually striped. The broad belt was much spotted and its upper part heavily shaded. There was a rosy tinge over the whole belt. The 3d satellite touched the limb of Jupiter, at ingress, at $9^h\ 56^m\ 44^s$ P. M. Its internal contact was at $10^h\ 6^m\ 15^s$ P. M. Although it entered on a part of the planet which was not bright, it could be followed only ten minutes.

1874, June 2.—There were peculiar white markings on the lower part of the equatorial belt of Jupiter; these were beyond the center at $8^h\ 25^m$. The 2d satellite touched the limb in occultation at $8^h\ 2^m\ 14^s{\cdot}3$; was wholly occulted at $8^h\ 9^m\ 42^s{\cdot}3$.

1875, April 11.—Observations on Jupiter began at midnight. The night was fine and the planet was near the meridian. The 1st satellite touched the limb in ingress at $0^h\ 37^m\ 52^s$ A. M. The internal contact with limb was at $0^h\ 46^m\ 16^s$. The satellite was last seen $1^h\ 2^m\ 51^s$, although it was upon the dark belt. The shadow was followed for some six minutes longer.

1875, April 23.—The 3d satellite of Jupiter was wholly off from the disc of the planet at $7^h\ 15^m\ 2^s$ P. M. The shadow of the 3d satellite touched the limb, at egress, at $7^h\ 43^m\ 7^s$ P. M. The shadow was wholly off at $8^h\ 1^m\ 51^s$ P. M. Measurements were made of both satellite and shadow. The diameter of the satellite measured $2''{\cdot}17$, of the shadow $1''{\cdot}95$.

1875, April 30.—The 3d satellite touched the following limb of Jupiter at $8^h\ 21^m\ 19^s{\cdot}3$. The internal contact was at $8^h\ 40^m\ 24^s{\cdot}3$. The shadow of the satellite was fully upon the disc at $9^h\ 48^m\ 9^s{\cdot}3$. The equatorial belt was slightly ruddy, and dark and white spots could be seen upon it. The 1st and 4th satellites were so nearly of the same size that I could distinguish them only by position.

1875, May 10, 8 to 9.30 P. M.—A white loop extended diagonally over more than half the equatorial belt of Jupiter.

1875, June 2.—Observations began at $7^h\ 55^m$ P. M. A very remarkable white spot was at once seen, nearly at the center of Jupiter's disc. It was followed by a very dark shading, so that it strongly resembled a satellite and shadow in transit. The white spot was so well defined as to be easily measured. The longer diameter (oblique to equatorial belt) was 1″·7. At 9 P. M. the white spot was approaching the limb of the planet, turning apparently with the planet, and was followed by one smaller and less distinct.

1875, June 4.—Observations began at $7^h\ 30^m$ P. M. At $7^h\ 54^m$ no white spot could be seen. At $8^h\ 15^m$ the white spot with the peculiar appearance of shadow following could be seen, as on June 2. It was, at this time, $\frac{1}{3}$ of the diameter of Jupiter, distant from the following limb. At $9^h\ 15^m$ the second white spot was seen, following the first, as on June 2. The 1st satellite touched the limb of Jupiter at $8^h\ 21^m\ 24^s$ P. M. The internal contact was at $8^h\ 26^m\ 19^s$ P. M. The satellite entered upon the planet below the broad belt, very white, more brilliant than the spot, but smaller and scarcely more conspicuous. The shadow of the satellite was first seen upon the disc at $9^h\ 23^m\ 44^s$ P. M.

1876, May 30.—Observations began at $9^h\ 39^m$ P. M. The broad belt on the disc of Jupiter was mostly above the equator. It was mottled with large white spots, somewhat rose-tinged. The 1st satellite as it approached the planet was of a dazzling whiteness; it entered upon the disc above the lower margin of the equatorial belt, yet it could be seen for only twelve minutes. The shadow entered on the disc about sixteen minutes later very black, but not round, the longer diameter being nearly perpendicular to equatorial belt. 1st satellite touched limb of Jupiter at $9^h\ 53^m\ 26^s$ P. M.; was at internal contact $9^h\ 59^m\ 22^s$. The shadow was wholly on the disc at $10^h\ 15^m\ 12^s$ P. M. The satellite was seen at $10^h\ 11^m\ 32^s$ P. M. It is possible that the satellite was faintly seen at $10^h\ 34^m\ 2^s$.

1876, May 31.—The peculiarity in the appearance of Jupiter is the presence of bright white spots on the upper portion of the disc, markings resembling faculæ on the Sun. The first satellite was seen to come out of eclipse at $9^h\ 44^m\ 41^s{\cdot}99$.

1876, June 15.—Observations on Jupiter began at $8^h\ 20^m$ P. M. The first satellite was known to be in transit, but could not be seen upon the disc. The shadow of the 1st satellite was wholly within the limb at $9^h\ 34^m\ 51^s{\cdot}9$. At $9^h\ 55^m\ 36^s{\cdot}9$ the 3d satellite was seen to come out from occultation. At $9^h\ 58^m\ 11^s{\cdot}9$ the 3d satellite was wholly out and shining with brilliant white light. At $9^h\ 20^m\ 42^s$ the 1st satellite was found, approaching the preceding limb, a dull gray figure, elliptic in shape, the major axis being perpendicular to equatorial belt. When this

satellite reached the limb it was as white as the 3d satellite, and round. The transit was made across the brightest part of the disc, and where there were no perceptible variations of brilliancy. The 1st satellite's last contact with limb was at $10^h\ 2^m\ 47^s$.

1876, June 22.—Observations began at $10^h\ 12^m$ P. M. The 1st satellite, known to be upon the disc, could not be found. The shadow was wholly on at $10^h\ 26^m\ 56^s$. The satellite was seen, dusky, oval and gray, from $10^h\ 55^m\ 33^s$ to $11^h\ 10^m\ 33^s$.

1877, June 13.—The shadow of the 2d satellite was seen, wholly entered upon the disc, at $11^h\ 20^m\ 45^s$. The satellite itself touched the limb at $11^h\ 36^m\ 07^s$; was at internal contact at $11^h\ 43^m\ 30^s$.

1877, June 19.—The 3d satellite touched the limb of the planet at $10^h\ 47^m\ 53^s$. The internal contact was at $10^h\ 59^m\ 10^s$. The 1st satellite reappeared from occultation at $11^h\ 4^m\ 51^s$. The ruddiness of the equatorial belt was noticed by several observers.

ART. VI.—*Revision of the Atomic Weight of Antimony;* by JOSIAH P. COOKE, Jr.

[Abstract of a paper, in the Proceedings of the American Academy of Arts and Sciences, xiii, 1, prepared by the Author.]

IN 1856, R. Schneider of Berlin made a very careful determination of the atomic weight of antimony and obtained for its value 120·3. His method consisted in reducing native antimony glance by means of hydrogen and his investigation was a model of its kind. In his paper* all the details of the experimental work are given and it is evident that every precaution was taken which the circumstances required. In 1857, Dexter by oxidizing the metal with nitric acid obtained for the same constant the much higher value 122·3,† and soon after this result was apparently closely confirmed by Dumas, whose analyses of antimonious chloride gave almost precisely 122.‡ The present investigation was undertaken with the view of reconciling if possible the large discrepancy between the results of these equally careful and accurate experimenters. It was suggested by the method, devised by the author, of precipitating sulphides which was described in a previous number of this Journal.§ This seemed to afford a very accurate method of making the synthesis of antimonious sulphide and thus of revising the analysis of Schneider. In carrying out the method, however, unexpected difficulties were encountered which are discussed at length in the original paper. Two of these arose

* Poggendorff's Annalen, xcviii, 455, June, 1856. † Ibid, c, 563, April, 1857.
‡ Ann. Chem. et de Phys., III, lv, 175, Feb., 1859. § This Journal, III, xiii, 427.

from the circumstance that the antimonious sulphide as usually precipitated occludes a small amount of tartaric acid on the one hand and of oxichloride of antimony on the other. These occlusions tend to produce errors in opposite directions, for when, before weighing, the red antimonious sulphide is heated to the point of its conversion into the gray modification, the tartaric acid is charred, and the carbonaceous residue increases the apparent weight of the product; while on the other hand the oxichloride of antimony is decomposed at the same temperature and the antimonious chloride, which volatilizes, tends to diminish the weight of the product. In the earlier determinations these causes of error were balanced as nearly as possible by regulating the conditions of the precipitation; but it was subsequently found to be possible to entirely prevent the occlusion of antimonious oxichloride, and in all the later determinations allowance was made for the small amount of carbonaceous residue, which was accurately estimated in every case.

In the preparation of pure metallic antimony, we were greatly guided by the experience of Mr. Dexter;* and our several products must have been very similar to his, as the following determinations of the specific gravities of the different buttons show. The observed values were reduced to 4° C., on the assumption that the coefficient of cubic expansion for antimony between 0° and 100° C. is for each degree 0·000033, as observed by Kopp. The letters here given will be used throughout the table to designate the various specimens. As might be supposed, the specimens were prepared at different times and at different stages of the investigation, but the results are united here for the convenience of comparison and of reference.

SPECIFIC GRAVITIES OF BUTTONS OF PURE METALLIC ANTIMONY.

Observations of J. P. C., Jr.		Observations of W. Dexter.	
A	6·7025	b	6·7087
B	6·7036	c	6·7026
C	6·6957	c	6·6987
D	6·7070	d	6·7102
E	6·7022	e	6·7047
F	6·7023	e	6·7052
Mean	6·7022	Mean	6·7050

The processes used in preparing the several buttons just referred to, the method by which the metal was brought into solution in its lowest condition of quantivalence, and the manner in which the antimonious sulphide was precipitated, collected, dried and weighed are all described at length in the original paper. The following table shows the results which were obtained.

* Poggendorff's Annalen, c, 564 (*l. c.*).

Synthesis of Sulphide of Antimony.

No.		Wt. in grams of Sb taken.	Wt. dissolved from balls.	Total weight of Sb used.	Wt. of red Sb_2S_3 dried at 180° C.	Per cent. of S in same.	Corresponding At. Wt. of Sb when S=32.	Wt. of black Sb_2S_3 dried at 210° C.	Per cent. of S in same.	Corresponding At. Wt. of Sb when S=32.
1.	A.	2·0036	0·2023	2·2059	3·0898	28·61	119·79	3·0881	28·57	120·02*
2.	E.	2·0017	0·2662	2·2679	3·1778	28.63	119·64	3·1764	28·60	119·82*
3.	E.	2·0113	0·0853	2·0966	2·9383	28·65	119·56	2·9350	28·57	120.03*
4.	A.	1·9973	0·0798	2·0771	2·9051	28·50	120·41	2·9021	28·43	120·85†
5.	E.	2·0019	0·1087	2·1106	2·9508	28·47	120·57	2·9486	28·42	120·89†
	Mean of 5 Determinations			-----	-----	28·572	119·994	-----	28·518	120·32
6.	A.	1·7638	0·0430	1·8068	2·5301	28·59	119·91	-- --	-----	----- ‡
7.	A.	2·0275	0·0894	2·1169	2·9639	28·57	119·97	-----	-----	... ‡
8.	B.	2·0116	0·0188	2·0304	2·8423	28·57	120·04	2·8410	28·53	120·23§
9.	B.	2·0027	0·1000	2·1027	2·9429	28·55	120·13	2·9409	28·50	120·41§
10.	E.	2·0015	0·1424	2·1439	3·0025	28·58	119·94	2·9981	28·49	120·47§
11.	E.	2·0038	0·3379	2·3417	3·2792	28·59	119·90	3·2788	38·58	119·95§
12.	E.	2·0014	0·2168	2·2182	3·1061	28·59	119·92	3·1022	28·50	120·44§
	Mean of last 5 Determinations			-----	-----	28·576	119·986	-----	28·520	120·298
13.	D.	2·0056	0·3787	2·3843	3·3369	28·55	120·14	3·3369	28·51	120·14‖
	Mean of the 13 Determinations			-----	-----	28·5731	119·994	-----	28·522	120·295

* Large residue of carbon, small sublimate.
† Small residue of carbon, large sublimate.
‡ Weight of black sulphide not found.
§ Both residue and sublimate small.

‖ No sublimate or loss of weight on drying and conversion. Residue large, but weighed and subtracted. The best determination, and as perfect as can be made under conditions.

We were for some time in doubt in what condition the sulphide of antimony ought to be weighed, in order to obtain the most accurate results. Our final judgment was that the errors already referred to would best be balanced, while others would be avoided, by weighing the sulphide, after it had been dried, at from 180° to 200°, but before it was actually converted into the gray sulphide. This conversion takes place between 210° and 220°, varying to that extent in different cases. The change, as we infer, is attended with a sudden evolution of heat, and the action is quite violent. Small particles of the material are frequently projected from the vessel, and we sometimes noticed that the surface of the platinum nacelle became coated with the familiar sublimate of sulphide of antimony. If there is oxichloride in the precipitate, there may be an additional volatilization of chloride of antimony at this time; but the main loss, as we have constantly observed, takes place before the point of conversion is reached. We therefore concluded that more trustworthy results could be deduced from the weight of the red sulphide dried, as we have described, than from that of the gray; and, as will be seen, this judgment was fully confirmed by subsequent experiments on the haloid compounds. We have, however, in all but two instances weighed the sulphide in both conditions, and we give the results of both weighings; and on comparing these results in determinations eight to thirteen inclusive of the table on page 43, which were made under the nearly identical conditions we have above indicated, it will be seen that the differences are far smaller with the red sulphide than with the gray, which shows conclusively that additional causes of error must have affected the last weights, —a circumstance which sustains our judgment.

In the first twelve determinations we did not estimate the amount of the carbonaceous residue, which is assumed to be balanced by the loss of chloride of antimony, although we always tested the purity of the sulphide of antimony by dissolving it in hydrochloric acid, as described. In determination numbered thirteen, we succeeded in precipitating the antimony without the usual occlusion of oxichloride. In this case, there was no evidence of sublimation nor loss during conversion, but a proportionally large carbonaceous residue, which was deducted from the weight of the sulphide; and the result of this determination, as will be seen, still further corroborates our conclusion. The same is true of the analyses of chloride of antimony made more recently, in which we dissolved crystallized chloride of antimony in a concentrated aqueous solution of tartaric acid, without using any excess of hydrochloric acid. In these cases also, the drying of the precipitate, and the conversion from the red to the gray modification, were attended with no appearance

of sublimation. Were we to repeat the investigation with our present knowledge, we should follow the indications of these last analyses; and instead of attemping to make the two chief errors as small as possible, and balance them, we should seek to remove from the solution all the free hydrochloric acid, and thus eliminate the error due to the occlusion of oxichloride. It would then, of course, be necessary to determine in all cases the carbonaceous residue, which might however be very large, without impairing the accuracy of the result. Still, our experience with these antimony determinations would lead us to fear that we might thus raise up as many hindrances as we avoided, and the determination we have given as No. 13 is sufficient for all purposes of comparison.

This point in our investigation was reached in the spring of 1876, and the results given above were presented to the American Academy of Arts and Sciences at their meeting of June 14th, 1876. But although they agreed so closely with the results of Schneider, and although the close confirmation of his analysis thus furnished by our synthesis seemed so conclusive, yet we could not rest satisfied so long as the great discrepancy between this value of the atomic weight and the higher number obtained by Dumas remained unexplained. We therefore determined to repeat his experiments before publishing our results. Accordingly, in the autumn of 1876, we purified and analyzed a large number of different specimens of antimonious chloride, and the results are united in the following table. Beginning with crystallized chloride of antimony obtained from different dealers, and pure in a commercial sense, we first boiled for several hours the melted chloride over finely pulverized metallic antimony, using for the purpose a glass retort, so tilted that the condensed liquid flowed back into the body of the vessel. When boiled in this way, the surface of the vapor is marked by a very well-defined ring in the neck of the retort; and by regulating the lamp this ring can readily be maintained very near the mouth, so that, while all the chloride of antimony condenses and flows back, any more volatile admixtures will gradually escape. The retort having been brought into its normal position, the chloride of antimony was next distilled; and, rejecting the first and last eighth which came over, the rest of the product was redistilled over strips of metallic zinc, and so on three or four times, rejecting at each distillation the first and last of the product. The final distillate was then still further purified by repeated crystallizations from fusion. As the fused mass solidifies quite slowly (indicating a large loss of latent heat), it is easy to arrest the process at any point, and pour off the still liquid portion from the crystals which have formed. The last can then be remelted, and the process

repeated, and so on indefinitely as long as the material lasts. In this way, from several kilograms of the commercial chloride we obtained the few grams of beautifully clear and perfect crystals used in our analyses. In the fifth preparation, the crystals were obtained not by fusion, but by cooling a saturated solution of the previously distilled chloride in purified sulphide of carbon. Such a solution, saturated at the boiling point of sulphide of carbon, deposits the larger part of the chloride, when cooled to the ordinary temperature. Naturally, every precaution was taken during the course of these preparations to protect this exceedingly hygroscopic substance from contact with moist air, and all the transfers were made in a portable photographic developing chamber, the air of which was kept dry by dishes of sulphuric acid. The portions for analysis were transferred, in this chamber, to tightly fitting weighing tubes; and, after the weight was taken, they were dissolved in a concentrated aqueous solution of tartaric acid, using about five grams of tartaric acid to each gram of chloride of antimony. The solutions were then diluted, and precipitated with argentic nitrate, weighing out in each case the amount required, so that only the least possible excess of the reagent should be added. The precipitates were washed and collected by reverse filtering in platinum or porcelain crucibles, and dried in an air bath at temperatures varying from 110° to 120°. They were weighed with the small disk of paper used in this process, and the invariability of the weight of these paper disks was repeatedly tested. Also, in several instances after removing the filter, the argentic chloride was heated to incipient melting; but, as in no case was its weight thus altered, this additional precaution seemed unnecessary. In the determination numbered 17, an attempt was made to ascertain whether the presence of antimony in the tartaric acid solution appreciably influences the precipitation of argentic chloride. In this analysis, the antimony was first separated from the solution by H_2S; and, the excess of this reagent having been removed by warming the filtrate with a small amount of ferric nitrate, the chlorine was precipitated in the usual way. The results, as will be seen, agree as nearly as could be expected with those obtained by at once precipitating the chlorine from the antimony solution."

The letters in the following table indicate different preparations, thus:—

a Was made from a crystallized chloride of Veron and Fontaine, Paris, which was purified in the manner described above.

b Was made from a crystallized chloride marked Rousseau Frères, Paris, purified as before.

c Was the same as *b*, again distilled and crystallized.

d, The same as *c*, after ten additional distillations.

e, The same as *d*, again distilled below 100° in a current of dry hydrogen gas.
f Was made with a crystallized chloride from Merck of Darmstadt, purified by repeated distillations and subsequent crystallizations from bisulphide of carbon, after first treating with chlorine as described beyond.
g, Same as *f*, but in this determination the antimony was first precipitated from the solution.

Analysis of Antimonious Chloride.

Determination of Chlorine.

No.	$SbCl_3$. grams.		AgCl. grams.	% of Chlorine. Cl=35·5. Ag=108.	At. Wt. of Sb. Cl=35·5.
1 *a.*	1·5974	yielded	3·0124	46·653	121·78
2 *a.*	1·2533	"	2·3620	46·623	121·93
3 *a.*	0·8876	"	1·6754	46·696	121·57
4 *b.*	0·9336	"	1·5674	46·516	122·46
5 *b.*	0·5326	"	1·0021	46·446	122·30
6 *b.*	0·7270	"	1·3691	46·588	122·10
7 *c.*	1·2679	"	2·3883	46·599	122·04
8 *c.*	1·9422	"	3·6646	46·678	121·66
9 *c.*	1·7702	"	3·3384	46·655	121·77
10 *d.*	2·5030	"	4·7184	46·635	121·87
11 *d.*	2·1450	"	4·0410	46·616	121·96
12 *e.*	1·7697	"	3·3281	46·524	122·42
13 *e.*	2·3435	"	4·4157	46·613	121·98
14 *f.*	1·3686	"	2·5813	46·659	121·75
15 *f.*	1·8638	"	3·5146	46·650	121·79
16 *f.*	2·0300	"	3·8282	46·653	121·78
17 *g.*	2·4450	"	4·6086	46·630	121·89
	Mean value for all analyses			46·620	121·94
	Theory when Sb = 122			46·608	122·
	" " Sb = 120			47·020	120·

If in calculating the per cent of chlorine from the results of the above determinations we use the atomic weights for silver and chlorine obtained by Stas (namely, Cl=35·457 and Ag=107·93), these per cents will be in each case very nearly 0·020 lower, and we shall obtain for the mean value 46·600 instead of 46·620. Moreover, on this assumption the atomic weight of antimony, deduced from Dumas's analysis of the chloride, would be 121·95 instead of 122. Again, if we use Stas's value of the atomic weight of sulphur (S=32·074) in calculating the atomic weight of antimony from our own results, on the synthesis of the sulphide, we should obtain 120·28 instead of 120; and, lastly, the values Sb=120·28 and Cl=35·457 give for the per cent of chlorine in antimonious chloride the value 46·931.

Here, then, is a most striking result: for these determinations confirm the value of the atomic weight of antimony

obtained by Dumas as closely as did the previous determinations confirm that obtained by Schneider. Evidently, there was a large constant error in one case or the other. Moreover, it appeared improbable that in either case any error could arise in the chemical process employed: for, in the first instance, we had a synthesis by one method confirming an analysis by a wholly different method; and, in the second instance, the analytical process employed is regarded as one of the most accurate known to science, and we had apparently shown that its accuracy was not impaired under the peculiar conditions present. It appeared, therefore, reasonable to assume that the results did truly indicate both the actual proportion of antimony in the sulphide of antimony and of chlorine in the chloride of antimony analyzed, and to look for the cause of the discrepancy to some impurity in one or the other compound. We therefore next sought to determine how much sulphide of antimony could be obtained from a given weight of chloride of antimony, hoping that by thus bringing the relations of antimony to chlorine and sulphur into close comparison the source of the error might be indicated.

The following table exhibits the results of these antimony determinations, as well as the general result of the assumed complete analysis of antimonious chloride. The per cent of chlorine taken is the mean of the first thirteen determinations of the previous table, as these only had been made at the time the second table was drawn up, and it therefore exhibits the results exactly as they were presented to us at this stage of the investigation.

ANALYSIS OF ANTIMONIOUS CHLORIDE.

DETERMINATION OF ANTIMONY.

	$SbCl_3$ taken in grams.	Sb_2S_3 obtained in grams.	% of Antimony when Sb : S = 120 : 32.*	% of Antimony if Sb : S = 122 : 32.†
1 *b.*	3·8846	2·8973	53·275	53·525
2 *b.*	5·1317	3·8417	53·473	53·725
3 *b.*	4·4480	3·3201	53·316	53·567
4 *b.*	4·5506	3·4009	53·882	53·633
5 *b.*	4·8077	3·6072	53·593	53·845
6 *b.*	4·2774	3·1958	53·367	53·618
Mean of all Analyses			53·401	53·652

MEAN RESULTS OF COMPLETE ANALYSIS.

Antimony, the mean of six determinations	53·401	53·652
Chlorine, " " thirteen "	46·611‡	46·611‡
	100·012	100·263

* Or assuming that $\frac{5}{7}$ of the gray sulphide is antimony, as deduced from actual synthesis.

† According to the generally accepted theory.

‡ When Cl = 35·5 and Ag = 108, according to Dumas.

As they at first presented themselves to us, these new results, so far from throwing light on the subject, only rendered the problem the more obscure and baffling. Towards interpreting them, however, one point seemed evident:—that, however little value our own experiments and those of Schneider might have in fixing the atomic weight of antimony, they had at least established, beyond all doubt, the proportion of this element in the gray sulphide weighed in our antimony determinations. For if we assumed, as those experiments indicated, that five-sevenths of the gray sulphide was antimony, then the amounts of antimony and chlorine found in the analysis of antimonious chloride just made almost exactly supplemented each other; while on the other hand, if this material was, as generally believed, pure Sb_2S_3, in which Sb : S = 122 : 32, then our determinations of one or the other of these elements must be greatly erroneous, and the excess obtained far too great to be explained by any known or probable imperfections of our methods. Of course, although the gray sulphide might contain, on the average, five-sevenths of its weight of antimony, it was a possible supposition that it might also occlude a constant amount of some undiscovered impurity, leaving the proportion of the sulphur to the antimony that which the atomic weights 122 and 32 required; and, were it not for our previous experience, this would have been the most obvious explanation of the discrepancy. Indeed, the new facts led us to re-examine this material, and review our previous conclusions, but with the same result as before. We could discover no impurity except the small amount of carbonaceous material which was well known and taken into the account, and in our later determination even this had been reduced to so small an amount as to be wholly insignificant.

[To be continued.]

ART. VII.—*On a new mineral, Pyrophosphorite: an Anhydrous Pyrophosphate of Lime from the West Indies;* by CHARLES UPHAM SHEPARD, Jr., Professor of Chemistry in the Medical College of the State of South Carolina.

THROUGH the kindness of Mr. C. C. Wyllie of London, England, I have been put in the possession of a few small fragments of a mineral phosphate from a new locality in the West Indies. Commercial considerations forbid at present the publication of the precise position of this deposit, but later I hope to be able to announce it, as also to give information with regard to the extent, mode of occurrence, and so on.

The mineral is generally snow-white and opaque, with here and there a slight tinge of bluish-gray. The white portion is dull and has an earthy fracture like magnesite; the grayish—constituting perhaps one-third of the mass—is small-botryoidal like gibbsite, and is somewhat the harder of the two.

The specific gravity varies between 2·50 and 2·53; hardness between 3 and 3·5. Before the blowpipe it melts with difficulty on the edges to a whitish enamel.

The following are the results of several chemical analyses of the mineral, as executed on two different portions of material:

	1st Series.	2d Series.	Mean.
Loss on ignition	0·390	------	0·390
Lime	44·50	44·424	44·462
Magnesia	3·04	3·141	3·090
Sulphuric acid	0·57	0·687	0·628
Phosphoric acid	50·97	50·629	50·799
Silica	0·30	0·434	0·367
Oxide of iron and alumina	----	0·437	0·437
			100·173

If we add together the adventitious ingredients, viz: the pyrophosphates of iron and alumina (taking an equal portion of phosphoric acid as the oxide of iron preponderates), the sulphate of lime, silica and loss on ignition, we obtain:

	Per cent.
Pyrophosphates of iron and alumina	0·874
Sulphate of lime	1·068
Silica	0·367
Loss on ignition	0·390
	2·699

There remain,

	Per cent.		
Lime	44·022	or 45·16	on raising the 97·474 per cent. to 100 per cent.
Magnesia	3·090	3·17	
Phosphoric acid	50·362	51·67	
	97·474	100·00	

The above composition agrees with the formula

$$2MgO,P_2O_5+4(5CaO,2P_2O_5)^* \text{ or } 2MgO,P_2O_5+4\left\{\begin{matrix}3CaO,P_2O_5\\2CaO,P_2O_5\end{matrix}\right.$$

which would require the following amounts of

	By calculation.	Actually found.
Lime	45·20 per cent.	45·16 per cent.
Magnesia	3·23	3·17
Phosphoric acid	51·57	51·67
	100·00	100·00

* Expressed according to atomic system $Mg_2P_2O_7+4\left\{\begin{matrix}Ca_3P_2O_8\\Ca_2P_2O_7\end{matrix}\right.$

The mineral therefore is (essentially) anhydrous ortho-pyrophosphate of lime with pyrophosphate of magnesia. The absence of water naturally suggests that its repository must have been in contact with some igneous formation. The proportion of phosphoric acid exceeds that of any known calcic phosphate, and it is likewise distinguished by its excess of phosphoric acid over the bases, in conjunction with almost total absence of water of chemical combination. This latter property separates it distinctly from the class of phosphates represented by the Mejillones and Raza deposits.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Direct Combustion of Nitrogen.*—Kämmerer has described an interesting lecture experiment to show the direct union of the nitrogen and oxygen of air. In a cylinder or globe of about two liters capacity filled with air, a piece of burning magnesium ribbon about thirty to forty centimeters long, is placed. When the combustion of the magnesium is ended, an intense odor of nitrogen tetroxide is perceived, and when the magnesium oxide has deposited, the characteristic color of this gas may be observed. By pouring into the jar a solution of potassium iodide acidified with acetic acid, and agitating, the brown color of free iodine at once appears, which strikes a deep blue color when starch solution is added.—*Ber. Berl. Chem. Ges.*, x, 1684, Oct., 1877. G. F. B.

2. *On the Relative Attraction of Oxygen for Hydrogen and Carbonous oxide.*—Bunsen, in his "Gasometric Methods," has given the results of an examination of the products formed when hydrogen and carbonous oxide are mixed with oxygen in quantity insufficient to burn them both completely, and exploded; from which he draws the conclusion that the atomic ratio of the combustion products ($H_2O : CO_2$) is always represented by simple numbers, changing from one to the other *per saltum* as the proportion of hydrogen varies. Horstmann has experimented anew in this direction and has obtained quite different results. He finds: 1st. That when electrolytic gas and carbonous oxide are mixed and exploded, following the method used by Bunsen, the proportion of the former gas being continually increased, vapor of water and carbon dioxide are formed in a constantly increasing ratio. Thus while the hydrogen, relatively to the carbonous oxide, varied from 0·25 : 1 to 2·33 : 1, from 20 to 70 per cent of the mixture being burned, the ratio of the combustion-products ($H_2O : CO_2$) varied from 0·8 : 1 to 4·5 : 1. Nothing like a sudden change of ratio was anywhere observed. 2d. That when to a mixture of carbonous oxide and hydrogen, increasing quantities

of oxygen are added and the whole exploded, as in E. v. Meyer's method, aqueous vapor and carbon dioxide are formed in a constantly increasing ratio, no "preference for rational values" being detected. Hence the author maintains that the division of the oxygen between these two combustible gases does not take place according to the law laid down by Bunsen. As to the cause of the discrepancy, he says that while his experiments were made with dry gases in dry tubes, he has observed that when aqueous vapor is present in the tube, less hydrogen and more carbonous oxide is burned. The ratio of $H_2O : CO_2$ is always lessened, and the more, the greater the amount of moisture present. On the other hand, in presence of carbon dioxide, more hydrogen and less carbonous oxide is burned. Now v. Meyer's experiments were made with moist gases, and Bunsen's partly with dry and partly with moist gases. Moreover, the variation in the ratio of the combustion-products is peculiar. As the oxygen increases, this ratio at first increases, reaches a maximum, when the amount of combustible gases burned is about 30 to 35 per cent, and then falls uniformly again to the limiting value reached when the combustion is complete. The law according to which the oxygen divides itself between the combustible gases, is thus expressed: The ratio of the aqueous vapor formed to the carbon dioxide is equal to the ratio of the unburned hydrogen to the unburned carbonous oxide, multiplied by an affinity-coefficient, which is independent of the proportion in which the combustible gases are present, but which varies with the relative quantity of oxygen added. The relation between this coefficient and the necessary quantity of oxygen being fixed empirically in the case of one proportion of such a mixture, it may be readily calculated for all others. This coefficient, in Horstmann's experiments, varied from 4·0 to 6·4, when between 20 and 70 per cent of the combustible gases were burned, the maximum being reached at 30 to 40 per cent. In other words, the ratio of the aqueous vapor to the carbon dioxide was 4 to 6·4 times as great as the ratio of the hydrogen to the carbonous oxide in the unburned residue. Since therefore relatively more hydrogen is always burned than carbonous oxide, the attraction of oxygen is greater for the former than for the latter gas. The variability of the affinity-coefficient itself is due to the fact that with the relative quantities of oxygen, the physical conditions change under which the reaction takes place. With a fixed quantity of oxygen it remains constant, not only when the proportion of hydrogen to carbonous oxide varies, but even when the unburned portions of the combustible gases are wholly or partially replaced by an indifferent gas with similar properties; as, for example, nitrogen.—*Ber. Berl. Chem. Ges.*, x, 1626, Oct., 1877. G. F. B.

3. *On the Sulphides of Platinum.*—Riban has called attention to the analytical properties of platinic and platinous sulphides. From his experiments he concludes, 1st, that platinic sulphide prepared in the cold or at the temperature of the water bath,

when taken alone, or at least in the absence of the metals of the 5th and 6th groups of Fresenius, may be considered as insoluble in alkali or ammonium mono- or polysulphides, and hence should be classed with mercury in the fifth group; 2d, that while by various special devices, such as pouring a solution of platinic chloride into a sulphide, drop by drop, or in fusing platinic sulphide with an alkali sulphide, a considerable quantity of platinic sulphide may be dissolved, yet that this is not a condition occurring in ordinary analysis; 3d, that in presence of metals of the sixth group, platinic sulphide dissolves notably in alkali or ammonium polysulphides. Arsenic, antimony, tin and gold effect this result, the quantity of platinum sulphide dissolved increasing with the amount of the other sulphides present; 4th, that platinic sulphide when mixed with the fifth group of metals, is not dissolved by the monosulphide, but is sensibly acted on by the trisulphide of ammonium, thus resembling copper; 5th, that platinous sulphide may be considered soluble or insoluble according to its physical state and the nature of the sulphide used. Platinous salts occur rarely in analysis, however, and then are easily converted into platinic compounds.—*Bull. Soc. Ch.*, II, xxviii, Oct., 1877.

G. F. B.

4. *On the Destructive Distillation of Phenol and Chlorbenzene.*—Kramers has examined the decomposition products obtained when phenol and chlorbenzene are distilled at a bright red heat. The phenol was allowed to flow slowly into a horizontal gas pipe kept at a bright red in a Hofmann's furnace. The products received were fractionated and yielded benzene, toluene, xylene, naphthalene, anthracene, and phenanthrene. Chlorbenzene thus treated gave diphenyl, parachlordiphenyl, paradichlordiphenyl and an isomer of it, and diphenylbenzene.—*Liebig's Annalen*, clxxxix, 129, 135, October, 1877. G. F. B.

5. *Boracic Acid.*—In the Annales de Chemie et de Physique, for November, M. L. Dieulafait publishes a very interesting discussion as to the origin of the boracic acid found in the Suffoni of Tuscany, and in connection with many saline deposits, especially those of Stassfurt. He traces the boracic acid in all cases to what he calls the normal sea water, and he opens his paper with the following broad generalization: "Toutes les substances salines existant en amas et en couches dans les terrains sédimentaires ont fait primitivement partie d'une mer normale. D'un autre côte, à toutes les époques, les mers ont eu une composition qui ne s'éloignait pas sensiblement de celle des mers de la periode actuelle." In order to establish this conclusion in the case of the borates he gives in the first place experimental evidence that the water of the Mediterranean contains at least two decigrams of boracic acid in each cubic meter, and, further, that on evaporating the brine boracic acid accumulates in the bittern until after the deposition of carnallite. In the second place, he insists that in the very characteristic deposits of Stassfurt the borates are found above the carnallite as we should expect, if these deposits were formed

as assumed, by the drying up of extensive salt lakes. Again, having confirmed the previous statements that the chief salt beds of the world are found on two geological horizons, the Lias and the middle Tertiary, he gives evidence that in the Maremma of Tuscany where the Suffoni occur, there is a saliferous basin of the Tertiary period, and he concludes that the Suffoni are not properly volcanic vents, but that the surface water percolating to the salt beds—heated it is true by volcanic agency—determines well-known chemical changes, from which result the peculiar acid vapors there discharged. But we can only give here the barest outlines of an argument, which is worthy of careful study.

We might question whether the very broad generalization of the author could be fully sustained, and think that he underrates the effect of local influences in varying the composition of different saline beds; yet he seems to us to have correctly interpreted the general order of the causes which have produced the deposits of borates, and in the experimental results cited above, to have added two very important facts towards the solution of this interesting problem of chemical geology.

M. Dieulafait also contributes in his paper some important facts in regard to the certainty and delicacy of three principal tests for boracic acid. He rejects the test with turmeric as unsatisfactory, in the presence of such a mass of salts as are found in bittern, and he finds the flame reaction by far the most sensitive as well as the most trustworthy of all the tests with which he has experimented. When the Bunsen lamp is supplied with pure hydrogen, he finds that the flame reaction will indicate the one-millionth of a gram of boracic acid. His method of applying the test is as follows: The material to be tested is first mixed with an excess of oil of vitriol, and this paste held in a loop of platinum wire is brought near—say within four millimeters—but never nearer than two millimeters to the visible mantle of the hydrogen flame, so that the flame may not be colored in the least by the sodium always present. If the assay contains boracic acid, the characteristic green coloration appears, which can be identified with absolute certainty, by means of a spectroscope, and the coloration can be most delicately observed by looking through the mantle of the flame tangentially.

J. P. C., JR.

6. *Photo-electric Phenomena.*—R. BORNSTEIN continues his experiments on the influence of light on the electrical tension in metals, and shows that the effect is not a thermo-electric one. The photo-electric series of the metals runs in this order:—Aluminium, gold, copper, platinum, silver. While the thermo-electric series is as follows:—Silver, platinum, copper, gold, aluminium.

His conclusions are as follows:—

(1.) In a circuit consisting of two different metals, a photo-electric current is generated whenever the two junctions are exposed to luminous radiations of different intensities.

(2.) When the same junction is exposed in one case to an increase of temperature, and in another to a more intense illumina-

tion, the thermo-electric and photo-electric currents respectively generated in these cases are opposed to each other in direction.—*Phil. Mag.*, Nov., 1877, p. 330. J. T.

7. HANKEL concludes from a series of experiments upon the photo-electricity of varieties of fluor-spar, that the electrical phenomena are largely due to the influence of the chemical rays of the spectrum, which cause chemical changes in the constitution of the crystal.—*Ann. der Physik und Chemie*, No. 9, 1877, p. 66. J. T.

8. *Specific Heat of air at constant pressure and constant volume.*—H. KAYSER has redetermined the specific heat of air at constant volume and constant pressure, by a modification of Kundt's method. The dust figures in the glass cylinder were formed by the transverse vibrations of steel rods excited by a violincello bow. A small cork piston attached to one end of the rod played in the glass cylinder, while a style affixed to the other end of the rod drew its vibrations on a phonautograph. These vibrations were compared with those of a tuning fork. H. Kayser concludes from his experiments that the true value of the velocity of sound in free air is 332·5 m. The value of k, the specific heat, has been variously assigned as will be seen from the following table:—

Masson	1·419	Cazin	1·41
Weissbach	1·4025	Röutger	1·405

H. Kayser concludes that the true value is $k=1{\cdot}4106$.—*Pogg. Ann.*, No. 10, 1877, p. 218. J. T.

9. *Fluorescence of the Retina.*—M. von Bezold and Dr. Engelhardt are led to the conclusion that the living retina also fluoresces under the influence of the same rays, which Helmholtz has stated exercise a fluorescent action on the dead retina.—*Phil. Mag.*, Nov., 1877, p. 397; *Trans. from Berichte d. baier. Akad. Math. Phys.*, June, July 7, 1877. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Reports of the United States Geographical Surveys west of the One-hundredth meridian*, in charge of First Lieutenant GEO. M. WHEELER, Corps of Engineers U. S. Army, under the direction of Brig.-Gen. A. A. HUMPHREYS, Chief of Engineers, U. S. Army. Vol. IV. Paleontology; quarto with 83 plates. Washington, 1877. Engineer department, U. S. Army.—This large volume, a contribution to the science of the country from the Wheeler expedition, under the War Department, comprises two important memoirs, as follows:

(1.) Report upon the Invertebrate Fossils collected in portions of Nevada, Utah, Colorado, New Mexico and Arizona, by parties of the Expeditions of 1871, 1872, 1873 and 1874; by CHARLES A. WHITE, M.D.: comprising general observations upon the collections and the periods they represent; a general view of the classification adopted; and descriptions, in successive chapters, of the

fossils of the Primordial, Canadian, Trenton, Subcarboniferous, Carboniferous, Jurassic, Cretaceous and Tertiary Periods; and illustrated by twenty-one plates.

(2.) Report upon the extinct Vertebrata obtained in New Mexico by parties of the Expedition of 1874; by Prof. E. D. COPE: comprising—(1) fossils of the Mesozoic periods, and geology of Mesozoic and Tertiary beds; (2) fossils of the Eocene; (3) fossils of the Loup Fork group; and illustrated by sixty-two plates.

Prof. White's valuable report has already been briefly noticed in vol. xii of this Journal (1876).

Prof. Cope's report embraces descriptions of a large number of vertebrate fossils, including species of fishes, birds, reptiles and mammals. Some of the general results arrived at with regard to the species of the Eocene of New Mexico are presented in vol. xii of this Journal, (1876, p. 297). The Loup Fork (or Loup River) group, as Dr. Cope observes, has now been identified at three widely separated localities: by Dr. Hayden in the Upper Missouri region, and by Dr. Cope in Colorado, and in New Mexico, the Santa Fé marls, first studied by Dr. Hayden, being of this horizon. The group underlies the "White River group" in the Missouri region, and has been regarded as Pliocene. Dr. Cope has described thirty-four species of Vertebrates from these beds, and points out the fact that while differing mostly in genera, and throughout in species, as far as now known, from those of the White River beds, they appear to be somewhat older in their geological relations than Pliocene, and hence, he has suggested (first in 1875) that they may be Upper Miocene. The genera favoring this supposition are stated to be *Amphicyon*, *Dicrocerus*, *Hippotherium*, *Aceratherium* (*Aphelops*), a *Mastodon* of the type of *M. angustidens*, *Pseudælurus*, *Steneofiber*. The species of the White River and Loup Fork groups differ widely in genera from those of the Eocene. The 62 lithographic plates of fossils illustrating Prof. Cope's Memoir are crowded with good figures. Nineteen of them are occupied with figures of parts of skeletons of different species of Coryphodon (Bathmodon of Cope 1872–1875) named by Dr. Cope, *C. cuspidatus*, *C. lobatus*, *C. obliquus*, *C. radians*, *C. latidens*, *C. elephantopus*, *C. molestus*, *C. simus*. Prof. Cope discusses several controverted points, which we leave without notice.

2. *Summary of field work of the United States Geological and Geographical Survey of the Territories*, under the charge of Dr. F. V. HAYDEN, for the season of 1877.—The work of the United States Geological and Geographical Survey of the Territories in charge of Dr. F. V. Hayden has been prosecuted with large success during the past year. The surveys in Colorado having been completed during the previous year, the parties prosecuted their work in a belt of country lying mainly in the western half of Wyoming, but also embracing adjacent portions of Utah and Idaho; all lying immediately north of the region embraced in the Survey of the 40th Parallel by Clarence King. The parties all took the field on the first of June.

The primary-triangulation party, upon the work of which that of all the topographical parties is based, was, as usual, in charge of Mr. A. D. Wilson, Chief Topographer. He took the field at Rawlins Springs, Wyoming. Near this point a base-line was carefully measured, from which a net-work of triangles was extended over the country from Fort Steel in Wyoming, westward to Ogden in Utah, a distance of about 260 miles, and north as far as the Grand Teton near the Yellowstone National Park. The area embraces about 28,000 square miles, and within it twenty-six primary stations were occupied and carefully computed, and, besides, many mountain peaks were located.* From the base-line at Rawlins, this work was carried north and west to the valley of Bear River in Idaho, where a check base was measured and the system expanded to the neighboring mountain peaks. Many remarkably long sights were taken from the loftier summits, several over 100 miles in length, and some of them 135 miles. From the Wind River Peak all the prominent points in the Big Horn Mountains to the northwest, were sighted, and the higher of the Uinta Mountains to the southwest, each about 165 miles distant. From these, connections were made at six points with the triangulation of the Survey of the 40th parallel.

In addition there were three other fully equipped divisions for topographical and geological work, and another under the direction of Dr. C. A. White, for special geological and paleontological work.

The area assigned to the Green River division, directed by Mr. Henry Gannett, with Dr. A. C. Peale, as geologist, was rectangle No. 56; the boundaries of which are meridians 109° 30′ and 112°, and parallels 41° 45′ and 43°. This area contains about 11,000 square miles, and embraces portions of Wyoming, Utah and Idaho. The party first surveyed that portion of the district which is drained by John Day's and Salt Rivers, two tributaries of the Snake. Thence, working southward and westward, they surveyed that portion of the district which is drained by Bear River.

With the exception of a small area of granite along the southwestern side of Wind River Mountains, and some basaltic outflows in the northwestern portion of the district, which are not older than late Tertiary age, Dr. Peale finds all the rocks to be of sedimentary origin. A comparatively small space is occupied by strata of Silurian age; the others range from Carboniferous to late Tertiary. A very large part of the district is occupied by beds of the Green River and Bridger groups, probably of Eocene age. Coal was found to exist in large quantity on Upper Bear River and its tributaries, and also on some of the branches of Green River, being especially abundant between Twin Creek and Ham's Fork. In the Malade valley, Dr. Peale observed deposits that are of later age than the Bridger group, but still, probably of Tertiary age.

The Sweetwater division in charge of Mr. G. B. Chittenden,

* A map showing the primary triangulations of this survey has quite recently been published.

with Dr. F. M. Endlich as geologist, covers rectangle No. 57, which is bounded by meridians 107° and 109° 30′, and parallels 41° 45′ and 43°, embracing about 10,800 square miles. The party took the field at Salt Wells station, on the Union Pacific Railroad, and worked northward and eastward. Owing to the advancing season, and the probable risk, on account of hostile Indians, about 800 square miles in the northeastern portion of the district were left unworked, and the party left the field on the 25th of September, near Fort Steele. Mr. Chittenden estimates that about five-eighths of the area surveyed are desert land; two-eighths mountainous, and one-eighth, of available value for habitation. A very large portion of the area is without the strong topographical features common to the surrounding region. Dr. Endlich reports that a very large part of the area of the district is occupied by strata of Tertiary age; that they found no older rocks than these after leaving the southern boundary, as they pushed their work northward, until they reached Fort Stambaugh. Here the oldest metamorphic rocks are exposed, with the Tertiary strata resting upon them. Going eastward from Fort Stambaugh upon the Wind River drainage, he found the full series of the sedimentary formations represented, beginning with the Silurian. Here, as well as in the mountains farther west, he reports abundant evidence of the former existence of glaciers. Marching southward the older sedimentary formations were found in the Seminole hills. Northward from Rawlins he reports the existence of mud-puff springs, covering an area of about two square miles, similar to the famous mud-geysers, but on a small scale.

The party assigned to the Teton division was in charge of Mr. G. R. Bechler, with Professor O. H. St. John as geologist. This division lies between meridians 109° and 112°, and parallels 43° and 44° 15′, and is drained by the upper branches of the Shoshone or Snake River. The district almost throughout is a mountainous one, the mountains presenting several comparatively short but distinct ranges, among which are the Mount Putnam, Blackfoot and Caribou Ranges; many peaks of which are largely covered with snow during the whole summer. The party left the field prematurely on account of the probable danger from hostile Indians, but not until after surveying 6,000 square miles.

Professor St. John reports the district to be one of unusual interest, and worthy of much and careful study. With the exception of the rocks of igneous origin, which he finds to have been of late Tertiary outflow, and quite extensive, the region is occupied by sedimentary or stratified rocks; which he refers to Lower Silurian, Carboniferous, Jura-Triassic, Cretaceous and Tertiary ages. They have all suffered great displacements in nearly all parts of the district. Besides these, he mentions other deposits in the valley of Snake River, later than the Tertiary strata just referred to, but still probably of Tertiary origin. It seems probable that these, as well as similar deposits observed by Dr. Peale, may prove to be of the same age as the Lake Beds of Dr. Hayden in Middle Park, the Uinta Group of Mr. King, &c.

The necessity of a careful examination of the various geological formations in the field, and of a review by a practical paleontologist of the various districts that have from year to year been surveyed by the different geologists of this and other surveys, has been long felt. Such a work indeed, was imperatively necessary before a consistent and comprehensive classification of the formations could be established. This duty was assigned to Dr. C. A. White, the paleontologist of this survey, and he took the field at the beginning of the past season, continuing his labors until its close. He has pursued his researches with such success as to demonstrate the necessity of continuing this class of investigations by various lines of travel across what is generally known as the great Rocky Mountain region, especially those portions of it that have been surveyed, as well as those in which the surveys are now in progress. Spending some time in the plains of Colorado immediately east of the Rocky Mountains, he crossed the mountains by way of Boulder Pass and Middle Park to the region of Yampa and White Rivers; thence, crossing Green River, he pushed his investigations westward along the southern base of the Uinta chain, as far as Great Salt Lake. Thence recrossing the Wasatch Mountains, he carried his work eastward across the Green River basin.

Among other important results, he has demonstrated the identity of the Lignitic series of strata east of the Rocky Mountains in Colorado with the Fort Union group of the Upper Missouri River, and also its identity with the great Laramie group of the Green River Basin and other portions of the region west of the Rocky Mountains; to which the labors of Dr. Hayden and Mr. Meek have long since plainly pointed.

He also finds the planes of demarkation between any of the Mesozoic and Cenozoic groups, from the Dakota, to the Bridger inclusive, to be either very obscure or indefinable, in the region traversed by him; indicating that whatever catastrophal or secular changes took place elsewhere during all that time, or extending within the limits of that region, sedimentation was probably continuous within what is now that part of the continent, from the earliest to the latest of the epochs just named. During the progress of the field work, large and very important collections of fossils were made, which are now being investigated.

Messrs. S. H. Scudder of Cambridge and F. C. Bowditch of Boston spent two months in Colorado, Wyoming and Utah, in making collections and observations in fossil and recent entomology, with very gratifying results. Mr. Scudder is making arrangements to add materially to his labors in this department, in connection with the survey.

Professor Joseph Leidy spent some time during the season in Green River Basin, making observations and collections for his large work on Rhizopoda, which is to form one of the quarto volumes of the survey.

The botany of the survey was represented during the past season by the two great masters, Sir Joseph D. Hooker, Director of the celebrated gardens at Kew, England, and Professor Asa Gray

of Harvard University. Their examinations extended over considerable portions of Colorado, Wyoming, Utah, Nevada, and California; but their own personal observations in the field will by no means be a measure of the extended range of the subject that will be covered by their report. They have for years been watching and noting the progress of the work of American botanists, and are ready to bring out some most important generalizations in their report. Dr. Hooker has, during many years past, prosecuted extensive botanical researches, not only in Europe, but in the Indies, from the Bay of Bengal across the Himalayas to Thibet; in the Antarctic regions, the southern parts of South America, and Africa; in New Zealand, Australia, Morocco, and Asia Minor. The joint report of these two savants will form a part of the eleventh annual report of the survey; and as it will embrace facts and views of world-wide comprehensiveness, it cannot fail to be of great scientific interest.

Previous to the year 1874 there were many indefinite rumors of the existence of strange and interesting remains of the habitations and implements, especially pottery, of a long-departed and forgotten people, who once occupied the region about the head-waters of the San Juan. The various government exploring parties that have traversed New Mexico and Arizona brought reports of other ruins in those regions, but no reliable accounts of those just referred to had ever been received.

In 1874, Mr. W. H. Jackson, in charge of the Photographic department, was directed to visit and report upon those ruins, in connection with his usual work; which he did, and the results were published in the Bulletin of the Survey. In the following year, Mr. W. H. Holmes, one of the geologists of the Survey, visited the same region and made a careful investigation of the ruins, and by his artistic skill, in connection with Mr. Jackson, brought back complete illustrations, as well as a full report. Upon his return Mr. Holmes conceived and successfully carried out the plan of representing these ruins by models in plaster. Mr. Jackson has taken up, and added to his department, the work of reproducing these models as well as those of ancient pottery found with them. In furtherance of this work he visited Northern New Mexico and Arizona, during the early part of the past season. He procured, among other important material, the necessary data for plastic representation of the pueblos or communal town-dwellings, of Taos and Acorna, models of which he has already constructed. Contact with Europeans has somewhat modified their ancient style of building, but one can readily see that they are constructed after their ancient prototypes, the dwellings of the forgotten people; forgotten, because the builders of the modern structures are as ignorant of the ancient builders as we are ourselves.

These are merely the salient features of the work which has been accomplished by the survey; the details will appear in its usual publications. H.

3. *Geology of Wisconsin, Survey of* 1873–1877. Vol. II, 768 pp. royal octavo, illustrated by several wood-cuts, lithographs and maps in the text, and accompanied by an atlas of maps.—The legislature of Wisconsin passed its first act for a geological survey in 1853, appointing Mr. E. Daniels, State-geologist; and its second in 1854, putting J. G. Percival in this position. Two carefully prepared Reports, of about 100 pages each, by Dr. Percival were published in 1856. In 1857, the survey was reorganized under Prof. James Hall, with whom was associated in 1859, Prof. J. D. Whitney with special reference to a study of the lead region. Dr. Carr and Mr. Daniels were engaged with Prof. Hall during the year 1858. A Report of this survey by Professors Hall and Whitney, making an octavo volume of 456 pages, was published in 1862. The volume is one of great value and especially on account of the descriptions of the mines, ores and minerals, by Prof. Whitney, which occupy 352 of its pages. A second volume was prepared by Prof. Hall, but it was not published. In 1873 a new survey was ordered by the State and placed under the charge of Dr. I. A. Lapham. Dr. Lapham held this position for two years, and annual reports were prepared and presented to the legislature, the publication of which the legislature failed to order. Dr. Lapham was displaced, unreasonably, in 1875, and the place given to Dr. O. W. White. But in February, 1876, it again passed into the hands of able geologists through the substitution of Prof. T. C. Chamberlain, of Beloit College, and under this arrangement, the new volume, above announced, has been prepared and issued.

This volume (called vol. II, that of Professors Hall and Whitney being vol. I) contains Dr. Lapham's annual reports for 1873, 1874, and Dr. White's for 1875 as introductory to the reports of the recent survey. These final Reports are:

I On the Geology of Eastern Wisconsin, by Prof. Chamberlain, 310 pages.

II. On the Geology of Western Wisconsin, by Prof. Roland D. Irving, 235 pages.

III. On the Geology and Topography of the lead region, by Prof. Moses Strong, 110 pages.

These Reports show that the work has been carried forward with ability and care, and with a full appreciation of what both science and the economical interests of the State demand. The topography, hydrology, forest and marsh vegetation and soils, are the subjects of valuable chapters; and then the distribution and characteristics of the several rock-formations are given with full details. Under the subject of erosion many remarkable facts are stated; and the frontispiece represents a lofty tower or "Stand" Rock, of Potsdam Sandstone, which is almost as remarkable as anything of the kind in Rocky Mountain scenery. The chapters on the Drift and other Quaternary deposits are of unusual interest. The third report, on the lead region, is, as its author states, much briefer than the subject demands. It serves

to supplement and extend the account by Prof. Whitney, adding the results afforded by the more recent mining operations and a further study of the regions.

The Atlas consists of a series of colored plates, illustrating in sections the geology of the State; and others for eastern Wisconsin, representing by color the distribution of the native vegetation, the drift, and the various kinds of subsoils. The chromolithographic work, which is beautifully done, is credited to the Milwaukee Lithographic and Engraving Company. The size of the most of the maps is inconveniently large—too large, we think, for the small amount of detail in the geology.

We cite from the volume the following facts and conclusions relating to the Wisconsin drift.

In the first place the facts with regard to the *driftless region*, which covers Southwestern Wisconsin and the borders of Minnesota and Iowa adjoining, described and mapped by Prof. J. D. Whitney, are brought out with additional observations; and the view of Dr. Percival, its first describer, and Prof. Whitney is sustained—that it has no bowlders or drift over its surface, and no water-worn material except in the beds of some of the streams. Its area is about 12,000 square miles.

The eastern border of the driftless area, as laid down by Prof. Irving, lies near a line running north from Freeport in Illinois to Grand Rapids. Thence, the boundary bends westward and northwestward near the line of the Green Bay and Minnesota railroad, and passes twelve miles north of Eau Claire. According to N. H. Winchell, it crosses the Mississippi just south of St. Paul, and then, to the south, enters Iowa over the southwest corner of the southeast town of Minnesota—that of Houston. The former absence of the ice is proved by the absence of gravel and stones, which suddenly cease on entering the region, and, as Prof. Irving states, by the character of the hills and ravines and the existence over it of numerous fragile sandstone peaks. The origin of this driftless feature of the region receives important elucidation from the facts observed by Professors Chamberlain and Irving, and the latter brings out, in his report, a new theory in explanation of it.

According to the observations of Prof. Irving, in connection with those of Prof. Chamberlain, the part of the great northern glacier that moved over Lake Superior was prolonged southwestward along several great depressions: (1) along the great Lake Michigan depression south-southwestward; (2) along the Green Bay Valley, which has a nearly parallel course (S. 35° W.) and extends nearly to Illinois; also, on the north, and more to the west (3) along a Keweenaw Bay depression, west of southwest in direction; (4) along a Bayfield Bay depression, as a part of, or a branch of, (5) the greater mass moving in the same direction from the western extremity of the Lake Superior depression. The Michigan Bay ice-mass stretched on south and west over Illinois. That of the Green Bay Valley was partly independent and hardly reached to Illinois. While those of the Keweenaw Bay depression and Western Lake Superior continued westward and south-

ward over Minnesota, and thence, as N. H. Winchell has shown, south to Iowa, where it was connected with the ice over northern Illinois.

The independence of the glacier-mass of the Michigan Bay depression and that of the long Green Bay valley is well proved by Prof. Chamberlain. Between the lake and the valley there is a low ridge called the Kettle Range—so named from the multitudes of ponds and pools over its surface. It is one to ten miles wide, and in some parts 300 feet high above its base. It continues southward nearly to Illinois, here bends around westward, and then turns northward along the west side of the valley and near the boundary of the driftless area. This Kettle Range is, according to both geologists, a true moraine ridge, and marks the east, south and west outlines of the Green Bay valley glacier. It consists of gravel, bowlders, sand and clay, unstratified, but with portions here and there rudely stratified. Furthermore, as ascertained by Prof. Chamberlain (the geologist in charge of Eastern Wisconsin) the glacial scratches made by the Michigan and Green Bay ice-courses converge southward toward the axis of the intervening Kettle Range, having a southwest direction on the Michigan Bay side and a southeast on that of the Green River Valley, thus pointing to the range as a moraine ridge between the two ice-masses or along their blending borders. Again, on the west side of the Green Bay Valley the glacial scratches run southwestward (while southeastward on the east side) and terminate in the Kettle Range of that side, thus marking out this western branch of the Kettle Range to be the course of the western border and western moraine of the Green Bay glacier. These facts are well displayed by Prof. Chamberlain on plate VII. The pond-depressions, or bowls and basins, of the Kettle Range are accounted for by this geologist on the supposition of alternate retreats and advances in the glacier, producing irregularities in the deposition of ridges of moraine material. He says also that there are numerous subterranean streams running from its base which undoubtedly have an undermining action and may have produced part of the depressions. Over the regions of Wisconsin between the Green Bay glacier and the more northern Keweenaw Bay glacier course the ice thinned out toward the great driftless area.

Professor Irving accounts for the absence of ice from the driftless area on the view that the great glacier of the north was divided by the deep and large channels of Michigan Bay and Lake Superior; that the great depth of the ice of Lake Superior forced it to follow the courses of the bay-depressions leading out of it, one part going south-southwestward along Michigan Lake and the Green Bay valley, and the rest west of southwest along the Lake Superior bays; and that thus the intermediate region was left iceless and driftless. He states that the surface is not higher than that of Wisconsin to the east, and is lower than that of Minnesota to the west; and hence that no argument can be drawn in favor of its escape from the ice by its altitude or by an elevation of the land. The explanation, though different, is closely

related to that given by Professor N. H. Winchell, in his Minnesota Geological Report for 1876, (published in 1877)* and that the hills of the granitic region stretching southwestward from Keweenaw Point, and from the south shore of Lake Superior farther west, prevented the extension of the great glacier from Lake Superior in that direction.

Both Professor Chamberlain and Professor Irving state that there is abundant evidence that during the Glacial era the continent in that part was higher above the sea-level than now; and that this elevation was followed by a depression below the present level —that of the Champlain period. The former states that "some of the streams have cut channels from one to three hundred feet deeper than those they now occupy," thus pointing to the fact of greater elevation during the Glacial era.

The chapters on the drift contain numerous facts with regard to the sources of the drift, proving transportation for 100 to 300 miles or more. The masses of native copper, which are very common, must have come, it is stated, from Keweenaw Point, or full 300 miles.† All the facts brought out on the glacial phenomena are of great significance and merit reproduction in this place; but we have to refer to the volume for the larger part of them. The observations on the Champlain deposits and terraces are also highly interesting.

Only two other facts we cite here. The Milwaukee brick have a cream-white color and this has been attributed to the absence of iron. But Professor Chamberlain states that the clay is *red*, and contains, according to analyses of the brick, nearly *five* per cent of oxide of iron; and that the absence of color must be due to the formation of a silicate of lime and iron, lime being also present in the clay. [The silicate is probably a variety of epidote, the formation of which in the Triassic red sandstone of the Connecticut valley where it adjoins trap dikes has often been observed by the writer to be connected with a discharge of the red color of the sandstone.]

The Niagara limestone of southern Wisconsin includes two distinct varieties of limestone which were of simultaneous origin; and, according to Professor Chamberlain, the compact kind corresponds to the solid coral limestone of modern coral reef seas, and the granular to the beach sand-rock, which is simultaneously made along the shores of the coral reef regions out of coral sands.

J. D. D.

* Noticed briefly in the number of this Journal for November last, vol. xiv, p. 422.

† Mr. A. H. Worthen states, in the first volume of his Report on the Geology of Illinois, that in the Mississippi bluffs at the mouth of Fevre River, a few miles below Galena (within the driftless area but not far north of its southern limits) he has observed small boulders of trap and porphyry, and Mr. A. H. Beebe informed him of the discovery of native copper at the same place. Prof. C. A. White, in his Report on the Geology of Iowa, states that a mass of native copper was found in Lucas county, near the middle of southern Iowa, which weighed more than thirty pounds. Galena is about 350 miles in a straight line south southwest from the Keweenaw copper region. and Lucas county is 170 miles southwest-by-west from Galena, or about 465 miles southwest-by-south from the Keweenaw region.

4. *Probable ancient outlet of the Great Salt Lake.*—It is believed that the explorations of the survey under the direction of Dr. Hayden, the past season, have determined the probable ancient outlet of the great lake that once filled the Salt Lake Basin. At the head of Marsh Creek, which occupies the valley, continuing directly south from that of the lowest Portneuf, is the lowest pass between the Great Basin and the drainage of the Columbia. In fact so low and flat is it, that a marsh directly connects the two streams, one flowing to the Bear River and the other to the Portneuf and Snake Rivers.

This fact was observed by the Survey in 1871 and 1872, but this district has been carefully examined the past season by Mr. Gannett and Dr. Peale.

5. *Siberian Steppes.*—Professor John Milne, in a paper entitled "Across Europe and Asia, Part V, from Ekaterinburg to Tomsk" (Geol. Mag., Oct., 1877), suggests that the material of the great plains of Siberia was deposited by the rivers while they were under floods caused by their being dammed about their mouths in consequence of the ice of the stream not having there melted. He shows that although the time of freezing of the waters in autumn differs but a week or so in the more northern and southern parts of the rivers, the time of melting in the spring often differs a month. Consequently the ice toward the mouth of the stream might serve as a dam during the breaking up of the cold season, and cause a spreading of the waters over the country; and "in past times, when the cold was probably more intense, these barriers of ice may have been more continuous and complete, and thus have kept the plains—which were then smaller than they are at present, because their northern ends were beneath the sea—more or less constantly covered with a lake of turbid water." Floods from this source occur now in Siberia. This barrier of ice differs from that suggested by Mr. Belt, in being of fluvial instead of Arctic-ocean origin. Professor Milne remarks that the Siberian plains are directly connected with the several river channels. Wherever there is a river, and especially a large one, a broad plain accompanies it; and as it expands in flowing northward, so with the plain. The widening of these plains continues until they unite to form that open flat expanse which fringes the Arctic Ocean. In some parts, the plains 1,000 miles inland are not over 250 feet above the sea-level.

6. *Mikroskopische Physiographie der massigen Gesteine*, von H. Rosenbusch. 596 pp. 8vo. Stuttgart, 1877. (E. Schweigerbart'sche Verlagshandlung.)—The present work forms properly a second companion volume to the *Mikroskopische Physiographie der petrographisch wichtigen Mineralien*, published by Dr. Rosenbusch in 1873. The many lithologists who have used with pleasure and profit his earlier work, will welcome the one which has just been given to the public. Like its predecessor, it is not a compilation of facts observed by others, but rather a record of the author's own wide and extensive observations. The general

method of classification adopted is as follows:—(1) orthoclase rocks; (2) orthoclase-nepheline, and orthoclase-leucite rocks; (3) plagioclase rocks; (4) plagioclase-nepheline, and plagioclase-leucite rocks; (5) nepheline rocks; (6) leucite rocks; (7) olivine, or chrysolite rocks. The special system of subdivisions of these classes will be gathered from the following example: Orthoclase rocks are divided into those which are pretertiary or *older* rocks, and those that are tertiary or recent, or *younger* rocks. First, the older rocks (I) contain quartz and are (1) *granular* in texture, granites, or (2) *porphyritic*, quartz porphyries, or (3) *glassy*, felsite-pitchstones; or they are (II) without quartz, and are (1) *granular*, syenites, or (2) *porphyritic*, porphyries with no quartz. Secondly, the younger rocks (I) contain quartz, and are (1) *granular* or *porphyritic*, liparites, or (2) *glassy*, obsidian, trachytic pitchstone, perlite, pumice; or they are (II) without quartz, including the trachytes and some glassy rocks.

The description of the individual rocks are very complete, especially the references to their microscopic character. A valuable portion of the work is the list of books and memoirs on lithological subjects covering about thirty pages. E. S. D.

7. *A Guide to the Determination of Rocks*, being an introduction to Lithology; by E. Jannetaz. Translated from the French by G. W. Plympton, C.E., A.M. 165 pp. 8vo. New York, 1877. (D. Van Nostrand.)—This little book has some very good points, but its usefulness is much impaired by the numerous inexcusable mistakes which appear in its pages:—for example, *muscovite* micas are stated to be rich in magnesia; the tesselated appearance of some andalusite crystals (chiastolite or macle) is described as due to the "envelopment of fragments of the rock in which they are found," (p. 36); pyrites (FeS_2) is said to be easily reduced to FeS (p. 109) etc. Besides, such words as Cordieritfels, Cyanitfels, Topfstein, Gallinace, etc., do not belong to the *English* language.

8. *Tables for the Determination of Minerals.* Based upon the tables of Weisbach; enlarged, and furnished with a set of mineral formulas, a column of specific gravities and some of the characteristic blowpipe reactions; by Persifor Frazer, Jr., A.M. 119 pp. 8vo. Philadelphia, 1878. (J. B. Lippincott & Co.)—The first edition of Professor Frazer's useful little book was noticed in volume ix of this Journal. The revised work, besides numerous corrections and minor additions, contains some new features, as for instance, the indication of the comparative rarity of the less prominent species.

9. *Tridymite in Ireland.*—Prof. A. von Lasaulx reports the discovery of tridymite in the trachyte-porphyry of County Antrim, Ireland.

10. *Anthracite of Pennsylvania.*—Mr. E. T. Hardman, in a paper in the Journal of the Royal Geological Society of Ireland (xiv, 200, 1876), attributes the change to anthracite in Pennsylvania to the series of trap-dikes to the eastward—not recognizing the fact that these trap-dikes are Triassic or Jurassic in age, and the nearest over fifteen miles distant from the coal.

III. Botany and Zoology.

1. C. Darwin. *The Different Forms of Flowers on Plants of the same Species.* (London, Murray; New York, D. Appleton & Co. 1877.) 12mo, 352 pp.—Circumstances have prevented an earlier notice of this volume, Mr. Darwin's last work upon the fertilization of flowers, the English edition of which was issued last summer, and the American reprint was not far behind. Although we ought to call attention to it, for the benefit of our general readers, and of the numerous local botanists of our country who have little access to foreign publications, yet the duty of reviewing the present volume was not urgent, as regards scientific novelty. For it is to a great extent a reprint, with alterations and considerable additions, of articles published some years ago in the Journal of the Linnæan Society, which excited much interest at the time, and the topics have become a part of our common knowledge. Still Mr. Darwin could not take up and reprint these papers without adding something to their value, and without making emendations or indicating qualifications. He adds, moreover, succinct notices of what has been done by others in the same field.

Six of the chapters relate to dimorphous blossoms, such as those of Primrose and *Houstonia*, including also the trimorphic cases, as of *Lythrum Salicaria* and some species of *Oxalis*. The seventh chapter discusses Polygamous, Dicœcious, and Gyno-Dicœcious Plants; the eighth and closing chapter is devoted to Cleistogamous Flowers.

For the dimorphous and trimorphous forms,—which needed a general appellation, and one to indicate the difference in the sexual organs themselves (calyx, corolla, etc., being alike in the two sorts),—Mr. Darwin adopts Hildebrand's term of *heterostyled*. When this term came to our notice as one intended for settled use, we took the opportunity in this Journal, a year ago, to suggest a fitter name, one which equally avoids the ambiguity of the older term, *dimorphous*, by indicating that the difference is in the stamens and pistils, not in the floral envelopes, and avoids the erroneous implication of the term *heterostyled*, that the style is only or mainly concerned. That is, we proposed the term *heterogone* or *heterogonous*. We were too late to ensure its adoption in this work. A fairly good term once in use ought not to be exchanged for a new one without very sufficient reason; and for the present purpose the term *heterostyle* is well enough. But the time has arrived when this peculiarity of structure must be indicated in descriptive botany as a part of the character of the genera or species which affect it: and here the inconvenience or equivocation of the phrase *Flores heterostyli* will sometimes be manifest. We think it probable that our term may find its place in systematic botany, and that we shall write *Flores hermaphroditi, heterogoni, moncœcei, dicœcei, gyno-dicœcei, polygami*, as the case may be.

One good set of terms for phytography we owe to Mr. Darwin and the present book, i. e., that of *gyno-dicœcious* and *gyno-moncœ-*

cious, for the case of those plants which produce their two kinds of blossoms as hermaphrodites and females, either on distinct individuals or on the same plant. So, likewise, the term *andro-monœcious* and *andro-diœcious* for the case of hermaphrodite and male flowers, on the same or on separate individuals. As to andro-diœcism, Mr. Darwin remarks that, after making enquiries from several botanists, I can hear of no such cases. The last summer brought one such case to light in our Cambridge Botanic Garden, perhaps exceptionally, but it raises the inquiry whether *Diospyrus Virginiana*, our Persimmon tree, may not be of this character. A solitary female tree here, and with no male tree in the town, sets fruit more or less in most seasons; but the persimmons are undersized and seedless. This year it was loaded with full-sized fruit, well furnished with seeds, the latter with a good embryo. The female flowers always bear stamens; but these are generally thought to be impotent; perhaps they usually produce some pollen; they doubtless did so upon this occasion.

As Mr. Darwin asserts, it would be convenient, and conduce to clearness, to restrict the Linnæan (and as now used loose) term *polygamous* to the species in which hermaphrodites, males, and females co-exist. This may occur in two ways, and possibly in three. The English Ash, as he remarks, is tricœcious, or has the three kinds on as many individual trees; while some Maples bear all three on the same tree.

If we rightly read a statement on p. 10, it implies that proterandry and proterogyny are known to occur only in "some few hermaphrodite plants." But it can hardly mean that, cases of it being common and obvious in many natural orders.

The first chapter of this volume is devoted to *Primula* and its allies; the second, to hybrid Primulas, mainly to the Oxlip, which is shown to be a spontaneous hybrid between the Cowslip and the Primrose. A note is added on some wild hybrid Verbascums, specially those between *Verbascum Thapsus* and *V. Lychnitis*, which cross with the greatest facility, and produce a series of forms which almost connect these two widely distinct species, yet the hybrids of the first generation are almost wholly self-sterile. Such cases as this and that of the Oxlip, which was formerly thought to prove that the Cowslip and the Primrose were mere varieties of one species, show, as Mr. Darwin remarks, "that botanists ought to be cautious in inferring the specific identity of two forms from the presence of intermediate gradations; nor would it be easy in the many cases in which hybrids are moderately fertile, to detect a slight degree of sterility in such plants growing in a state of nature and liable to be fertilized by either of the parent species."

The third chapter takes up in succession other heterogone dimorphous flowers, particularly those of some species of Flax, and of *Houstonia*, *Mitchella*, and other *Rubiaceæ*. The fourth chapter discusses the trimorphous flowers of the same category, notably of *Lythrum Salicaria*, of which we gave an abstract when this

striking case was first brought to light. Our *Nesæa verticillata* is also referred to, the trimorphous species of Oxalis considered, and finally *Pontederia*, the only monocotyledonous genus now known to be heterogone. The trimorphism in this genus was detected a few years ago by Fritz Müller in Brazil; also recently, in *P. cordata*, our common Pickerel-weed, by Mr. Leggett of New York. Chapter VI is a detailed discussion of experiments on the illegitimate offspring of heterogone flowers; i. e., offspring produced by breeding within the limits of the same form, short-styled with long-stamened, or the converse. The conclusion is that in all points "the parallelism is wonderfully close between the effects of illegitimate and hybrid fertilization. It is hardly an exaggeration to assert that seedlings from an illegitimately fertilized heterostyled plant are hybrids formed within the limits of one and the same species. This conclusion is important; for we thus learn that the difficulty in sexually uniting two organic forms, and the sterility of their offspring, afford no sure criterion of so-called specific distinctness. "If one were to cross two varieties of the same form of *Lythrum* or *Primula* for the sake of ascertaining whether they were specifically distinct, and he found that they could be united only with some difficulty, that their offspring were extremely sterile, and that the parents and their offspring resembled in a whole series of relations crossed species and their hybrid offspring, he might maintain that his varieties had been proved to be good and true species; but he would be completely deceived." The cause of this sterility between individuals which may have sprung from the very same parent or parents and from the same capsule, must evidently be in their reproductive organs only, and in some recondite incompatibility of their sexual elements, not in any general difference of structure or constitution. And Mr. Darwin effectively argues that the same holds in case of distinct species of the same genus. "We are indeed led to this same conclusion," he adds, "by the impossibility of detecting any differences sufficient to account for certain species crossing with the greatest ease, whilst other closely allied species cannot be crossed, or can be crossed only with extreme difficulty. We are led to this conclusion still more forcibly by considering the great difference which often exists in the facility of crossing reciprocally the same two species; for it is manifest in this case that the result must depend on the nature of the sexual elements, the male element of the one species acting freely on the female element of the other, but not so in a reversed direction." Sterility of hybrids ceases to be a criterion of species.

The 6th chapter follows up the subject in a series of concluding remarks. It refers to those cases of more or less marked reciprocal differences in stamens and style which are unaccompanied by any difference in size or form of pollen-grains; and it tabulates the difference in pollen-grains of the two sorts. "With all the species in which the grains differ in diameter, there is no exception to the rule, that those from the anthers of the short-styled

form, the tubes of which have to penetrate the longer pistil of the long-styled form, are larger than the grains from the other form." "This curious relation led Delpino (as it formerly did me) to believe that the larger size of the grains is connected with the greater supply of matter needed for the development of their longer tubes." But it proved that, in many cases where the pollens differ much in size, the styles differ moderately in length, and *vice versa*, and that in plants generally, there is no close relationship between size of pollen and length of style (the grains being of the same size in *Datura arborea* and in Buckwheat, while the style of the one is nine inches long and of the other very short); yet still "it is difficult quite to give up the belief that the pollen grains from the longer stamens of heterostyled plants have become larger in order to allow of the development of longer tubes." A list of the genera, thirty-eight in number, positively known to be heterogonous is given. They belong to fourteen orders; but almost half the genera belong to the order *Rubiaceæ;* with the exception of *Pontederia*, they all have regular corollas, and all depend on insects for fertilization. "Plants which are already well adapted by the structure of their flowers for cross-fertilization by the aid of insects often possess an irregular corolla, which has been modeled in relation to their visits; and it would have been of little use to such plants to become heterostyled. We can thus understand why it is that not a single species is heterostyled in such great families as the *Leguminosæ*, *Labiatæ*, *Scrophulariaceæ*, *Orchideæ*, etc., all of which have irregular flowers."

Chapter VII relates to Polygamous, Diœcious, and Gyno-diœcious plants. A few genera are mentioned which have probably passed on from the heterogone condition to the diœcious. *Coprosma* is perhaps the best marked case; and *Mitchella* and *Epigæa* show tendencies in the same direction. On the other hand, Mr. Darwin's observations on *Euonymus Europæus* are "very interesting, as showing how an hermaphrodite plant may be converted into a diœcious one." *Rhamnus lanceolatus* shows the same thing more incipiently. Of Gyno-diœcious plants, which bear hermaphrodite and female flowers, but no separate males, and which show no obvious tendency towards diœcism, the principal illustrations are from *Labiatæ*, such as Thyme, *Nepeta Glechoma*, Mint, etc.

The eighth and last chapter is devoted to Cleistogamic flowers. All ordinary cases of two kinds of flowers are evidently arranged to favor or secure cross-fertilization. But there is a good number of plants, such as most Violets, which besides their ordinary and showy blossoms, produce others which fertilize and fructify without opening. These are always small and inconspicuous; and they so much resemble early flower-buds of arrested development that we were accustomed to designate them as flowers precociously fertilized in the bud. In some if not most cases this would be a quite correct representation of them; and there are well known instances in which—at least in cultivation—the earlier

of the ordinary flowers self-fertilize without expanding or fully completing their development; but in others these comparatively minute and ever closed flowers are profoundly modified structurally in reference to their function. Dr. Kuhn, in 1867, gave them the appropriate name of *flores cleistogami*, *cleistogamic*, or as we prefer *cleistogamous* flowers. The literature of the subject may mostly be gathered from this chapter, in which all that is known of these blossoms is condensed. We cannot here attempt a recapitulation. In brief, "they are remarkable for their small size and from never opening, so that they resemble buds; their petals are rudimentary or quite aborted; their stamens are often reduced in number, with the anthers of very small size, containing few pollen-grains, which have remarkably thin transparent coats, and which generally emit their tubes while still enclosed within the anther-cells; and lastly the pistil is much reduced in size, with the stigma in some cases hardly at all developed. These flowers do not secrete nectar or emit any odor. . . . Consequently insects do not visit them; nor if they did could they find an entrance. Such flowers are therefore invariably self-fertilized; yet they produce abundance of seed." Indeed they are far more fertile than the ordinary flowers of the species, which are apt to be sterile. The latter are in most cases adapted to the visits of insects; in some, such as Orchids, they are dependent upon this agency for such fertility as they possess.

Cleistogamous flowers are known in about twenty-four natural orders, yet not in a large number of genera. The list given by Kuhn, and corrected and extended by Darwin, is likely to be enlarged; but in one particular it may be diminished, for *Ruellia*, *Dipteracanthus*, and *Cryphiacanthus* are really all of one genus. We can add another genus and natural order to the list. For, while writing this notice, Mr. C. G. Pringle, of Charlotte, Vermont, calls our attention to its occurrence in *Dalibarda repens*, of the order *Rosaceæ*, and sends excellent specimens which exemplify it. This should confirm the genus, which, as restricted to its original and proper species, and irrespective of this newly-discovered peculiarity, surely ought not to be combined with *Rubus*.

Cleistogamy is an arrangement to secure a certain and abundant supply of seeds with the least expenditure; it is a corrective of or guard against the dangers of cross-fertilization dependent on either winds or insects; but no cleistogamous species is known which has not ordinary flowers also, mostly corolliferous and insect-visited, some specially modified for such visits, either by heterogone dimorphism or by special structure such as that of Orchids and Violets, but some anemophilous, such as a few rushes and grasses. Among the latter, it is singular that one of the earliest known and strongly marked cases, that of *Amphicarpum* (*Milium amphicarpum* Pursh), should be overlooked.

Since this notice was written, Mr. Pringle has announced to us the discovery of cleistogamous flowers regularly occurring within the leaf-sheaths of *Danthonia spicata* and its allies, also in *Vilfa* and other grasses. A. G.

2. *Ferns of North America.* By DANIEL C. EATON, of Yale College. (S. E. Cassino, Salem, Mass.) Part I, pp. 20, and three plates, representing four species. 4to, 1877.—We are glad that our country is not to lag behind others in furnishing to amateurs as well as to serious and more general botanists the great facilities which figures give for the study of Ferns. Books of this kind, of various pretension and merit, abound in Great Britain, and there is evidently a great demand for them. But our own fern-fanciers are becoming numerous and active, and this work will aid them and bring many more into the field. At least our botanists and botanical students want it. And this work seems to us well planned to meet all these requisitions. Well executed it certainly is, thus far. The paper and typography are most excellent; and the plates, from colored drawings by J. H. Emerton, are beautiful specimens of chromo-lithography. Plate II, representing *Cheilanthes vestita* and *C. Cooperæ* (a new species, detected in California by Mrs. Elwood Cooper, whose name it bears), is to our mind the best; and the synopsis of the species of the genus, arranged under the sections, was a good thought. The figure of *Asplenium serratum*, a tropical American Fern, recently discovered in Florida by Dr. Garber, is well managed and characteristic; but by lamplight the green is too blue. Under the same conditions the *Lygodium*, which is well chosen for a leader, seems too pale and dull. A little more practice will set this all right. The prospectus informs us that a fascicle will be published every two months, or thereabout, at a dollar each; and that it is proposed to figure all the species indigenous to the United States. This is an excellent beginning. That it will be kept up to the standard, and will be critically accurate, we cannot doubt; for no one knows our Ferns half so well as Professor Eaton, and no one can describe them better. We hope, and we do not doubt, that the sale will warrant this enterprise, and ensure its continuance and completion.

A. G.

3. *Notes on Botrychium simplex*, by GEORGE E. DAVENPORT, 1877.—Here is more Fern-lore, an exhaustive monograph of a pygmy Fern, which was first described in this Journal (for 1823, vol. vi, in a page which is now reproduced in fac simile), and of a closely allied species *B. matricariæfolium*, from which it is now distinguished by the radical or rather subterranean sterile branch of the frond. Two large quarto plates crowded with figures (48 in number), illustrate the forms which these two species assume in this country, and the account of them fills 22 pages of letter-press of the same size. The result of this thorough treatment is to confirm the view taken by Milde; but it is left doubtful which of the two Professor Hitchcock had, if indeed he did not have both. As the title-page gives neither name of publisher nor place of publication, we conclude that this elaborate paper is privately printed. The page of preface shows that this was done at Salem, and that the figures are heliotype reproductions of Mr. Emerton's outline drawings. It is stated that "if the publication of these notes shall

prove to be of any service to fern-students [which it surely will], they will owe it entirely to the generosity of Mr. Robinson."

A. G.

4. *Researches in regard to the influence of light and radiant heat upon transpiration in plants*, by J. WIESNER (translated in Ann. d. Sc. Nat., Sept., 1877, from Sitzungsb. der k. Akad. d. Wissensch., 1876, t. 74). Wiesner prefaces his memoir by a short historical account, of which we here give an abstract. Near the middle of the last century, Guettard demonstrated by rude experiments that light favors transpiration. Unger, and, later, Sachs have supposed that the movements of stomata under the influence of light are the cause of its action upon transpiration. Barthélemy has, however, shown that the opening of stomata depends largely upon the pressure of gas in the interior of plants; when this pressure is slight, stomata can remain closed even in the light. The opening of stomata is according to him to be looked upon as an effect of the increased transpiration and not its cause. Dehérain and Risler have stated that those rays of light which are most efficient in decomposing carbonic acid, are the most active in transpiration. Lastly, Baranetzky has shown that transpiration is not always proportional to the intensity of light. To explain this he assumes that there is, in the plant, a sensitiveness to the action of light, which may be exhausted by too frequent excitation.

Wiesner, in the memoir now noticed, gives a detailed account of his own experiments, and presents the following conclusions. A part of the light, which has traversed chlorophyll is transformed into heat; there results an elevation of temperature within the tissues, and a consequent increase of tension of aqueous vapor in the intercellular spaces. The excess of vapor escapes through the stomata. The rays which correspond to the absorption bands of the chlorophyll spectrum, and not the rays which are most luminous, are those which are efficient in transpiration; rays which have passed through a solution of chlorophyll exert only a feeble influence upon transpiration. Other coloring matters, xanthophyll, for instance, acts like chlorophyll, but less powerfully. Wiesner has shown that active transpiration in young leaves of maize can take place when the stomata are closed; on the other hand, the transpiration of *Hartwegia comosa* was very feeble in the dark, although the stomata were widely open. Also that the dark heat-rays are less active in transpiration than the luminous rays, and that the ultra-violet rays have no influence at all; that, whatever may be the nature of the rays, they act solely by elevating the temperature of the tissues.

G. L. G.

5. *Ueber Botrydium granulatum;* by J. ROSTAFINSKI and M. WORONIN.—This is an interesting paper which appeared in the Botanische Zeitung of Oct. 12. The investigations were carried on simultaneously by Rostafinski in Strassburg and Woronin in St. Petersburg, the plates, which are beautifully done, being drawn by Woronin. As is well known *Botrydium granulatum* is a unicel-

lular Alga of a more or less pyriform shape, from whose smaller end grows a branching root-like process by which the plant is fastened in the moist ground. Small as it is, it is amply provided with reproductive bodies as will be seen by the following: 1st. The contents of the pyriform portion may change into a large number of zoöspores each provided with a cilium. 2d. If the plant becomes somewhat dry the pyriform portion shrivels, and the root fibres divide up into a number of cells which may be transformed in either of two ways; if placed in a moist position their contents are transformed into zoöspores like those already described; or else each cell pushes out a hyaline root-like process which then grows so as to push the rest of the cell above ground forming what is known as the hypnospore. In the hypnospore, zoöpores are produced which have one cilium. 3d. By the germination of the uniciliate zoöspores individuals are produced which bear the spores proper. The latter may be either green or red, and in them are formed zoöspores which are furnished with two cilia and which, after escaping from the spore, unite in twos or some larger number so as to form what Rostafinski would call an isospore or, as is more generally expressed, a zygospore.

The cells of *Botrydium* sometimes bud out at the sides and the budding processes, after a time, send out hyaline roots and finally separate from the mother cell, forming a new individual. In this connection, we would refer to a plant which we found during the past summer at Eastport, Maine, and Gloucester, Mass., where it was not rare on rocks and wharfs at half-tide. The species seems to be identical with *Cœliolum gregarium* A. Br., found by Brown and afterwards by Pringsheim at Heligoland, in company with *Calothrix scopellorum* Ag. with which it is also associated on our own coast. The mode of growth, by means of buds, which afterwards send out a hyaline root, and then separate from the mother cell, is the same as that described in *Botrydium*. The sporiferous plant also bears a strong resemblance to *Botrydium granulatum*, and it seems that the somewhat anomalous genus *Cœliolum*, at least *C. gregarium*, should be included in *Botrydium*. W. G. F.

6. *Om Spetsbergens marina Klorofyll förande Thallophyter.* By Dr. F. R. Kjellman.

Ueber die Algen Vegetation des Murmanschen Meeres. By Dr. F. R. Kjellman.

Bidrag till kännedomen af Kariska hafvets Algvegetation. By Dr. F. R. Kjellman.

The above named articles, which are extracted from the proceedings of the Swedish Royal Academy are important contributions to our knowledge of arctic Algæ. Dr. Kjellman as botanist of the expedition to Nova Zembla under the command of Nordenskiöld has had exceptional advantages for the study of the vegetation of a region which is rarely visited. Although, of course, the number of species is small, a number of interesting *Phæosporæ* were found. Dr. Kjellman regards as a characteristic of the Nova Zembla coast, in striking contrast to that of Norway, that there is an almost entire absence of littoral *Fuci* and indeed of all littoral

species whatever. The most prolific region was in water about ten fathoms deep. W. G. F.

7. *Felci e Specie nei Gruppi affini raccolte a Borneo.* By Vincenzo Cesati. *Prospetto delle Felci raccolte dal Signor O, Beccari nella Polinesia.* By Vincenzo Cesati, Napoli.—The former article forms a pamphlet of forty-one pages, with four plates, in which the writer enumerates the higher cryptogams of Borneo and describes a number of new species. The latter article is much shorter and contains descriptions of about thirty new species and varieties.

W. G. F.

8. *Notes on Botrychium simplex* Hitch.; by George E. Davenport, 1877. Salem, Mass. 4to, pp. 22, tab. 2.—*Botrychium simplex* is a little Fern which was originally described and figured in this Journal in 1823 (vol. vi, p. 103), by President Hitchcock. For many years it was very little known, and was confused with several other species of the same genus. Dr. Milde, in vol. xxvi, of the Nova Acta Acad. Nat. Curiosorum, was the first to clearly define it, to associate with it forms more highly developed than the specimens known to President Hitchcock, and to illustrate the species with figures of its several forms and variations. In the present paper Mr. Davenport has thoroughly discussed the plant in all its forms, and has carefully pointed out its real differences from its nearest ally. He gives a great number of stations where it has been discovered, and in the two plates he has had figured many specimens of this species and of other species which have been mistaken for it. The whole forms an interesting and valuable contribution to the history of North American Ferns; and it is to be hoped that the author will be encouraged to publish the results of his studies upon other species. D. C. EATON.

9. *Note on the Habits of young Limulus;* by Alexander Agassiz.—Mr. C. D. Walcott has called attention to the fact that when collecting fossils he finds large numbers of Trilobites on their back;* from this he argues that they died in their natural position, and that when living they probably swam on their backs. He mentions, in support of his view, the well known fact that very young Limulus and other Crustacea frequently swim in that position. I have for several summers kept young horse-shoe crabs in my jars, and have noticed that besides thus often swimming on their backs, they will remain in a similar position for hours, perfectly quiet, on the bottom of the jars where they are kept. When they cast their skin it invariably keeps the same attitude on the bottom of the jar. It is not an uncommon thing to find on beaches, where Limulus is common, hundreds of skins thrown up and left dry by the tide, the greater part of which are turned on their backs. An additional point to be brought forward to show that the Trilobites probably pass the greater part of their life on their back, and die in that attitude, is that the young Limulus generally feed while turned on their back; moving at an angle with the bottom, the hind extremity raised, they

* Ann. Lyc. Nat. Hist., xi, p. 155, 1875; Twenty-eighth Report N. Y. State Museum, Dec., 1876.

throw out their feet beyond the anterior edge of the carapace, browsing, as it were, upon what they find in their road, and washing away what they do not need by means of a powerful current produced by their abdominal appendages.—*Communicated by the Author.*

10. *New Species of Ceratodus, from the Jurassic;* by O. C. MARSH.—Among the interesting vertebrate remains recently found in the Jurassic of Colorado is a tooth of a *Ceratodus*, in good preservation. The specimen is a left lower dental plate, having the inner side convex, and the outer divided into five prominent projections, which are separated by four notches. The front projection is longest, and most pointed. The plate is attached to a portion of the dentary bone, as shown in the accompanying figure.

Ceratodus Güntheri.
Natural size.

The length of this dental plate is 20 mm., and the transverse diameter 11 mm. The species is the first Mesozoic *Ceratodus* found in this country, and hence of much interest. It may be named *Ceratodus Güntheri*, in honor of Prof. A. Günther of the British Museum. The geological horizon of this species is in the Atlantosaurus beds of the upper Jurassic.—*Communicated by the Author.*

IV. ASTRONOMY.

1. *The November Meteors.*—At my request, Messrs. Benjamin Vail and John P. Carr, students in the State University, kept watch last night for the November meteors. The early part of the night was too cloudy for observations, but before two o'clock this morning (the 14th) the sky had become quite clear. In one hour and fifty minutes—from 1.55 to 3.45—fifty-four meteors were counted by the two observers. This was at the rate of thirty per hour. Nearly all were Leonids—that is, the point from which they radiated was in the constellation Leo. A few of the number were as large as first magnitude stars, and left trains which continued luminous for several seconds. The appearance of so large a number ten or eleven years after the maximum displays of 1866 and 1867 is quite unexpected.

Bloomington, November 14, 1877. DANIEL KIRKWOOD.

2. *On Schmidt's Nova Cygni.*—Mr. Copeland, in a letter to the Astronomische Nachrichten, from Lord Lindsay's Observatory at Dunecht, dated September 5, says: "On September 2, 1877, I examined this star with the 15-inch refractor of this observatory. It was found to be of the 10·5 magnitude and of a decided blue tint, especially when viewed in the same field with the reddish star B.D.+42° 4184 which it precedes by about 25ˢ. Viewed through a low power eye-piece and a powerful direct vision prism, held between the eye and the eye-piece, the light of the star was found to be absolutely monochromatic. A single prism Browning spectroscope with a slit, but without a cylindrical lens, gave a star-like image without a trace of continuous spectrum. A few hurried measures were all that could be obtained; they indicated a wave-

length of 512 mm.; but great uncertainty attaches to this determination as a slight derangement of the spectroscope prevented the introduction of a comparison spectrum. On September 3, Lord Lindsay made thirteen measures of the wave-length, with a Grubb spectroscope giving a dispersion of $3\frac{1}{2}°$ from B. to Z. The very reliable result was 498·6 mm. A single measure of mine gave 496·1. It will be at once seen that the light of this remarkable star is most probably identical in wave-length with the nitrogen line 498·7, or possibly with one or both of the lines 500·4 and 495·66, (D'Arrest, Undersögelser over de nebulose Stjerner, Copenhagen, 1872) occurring in the spectra nebulæ. Lord Lindsay found 500·8 mm. and 493·5 as limiting wave-lengths between which the whole width of the line must be enclosed. Bearing in mind the history of this star from the time of its discovery by Schmidt it would seem certain that we have an instance before us in which a star has changed into a planetary nebula of small angular diameter. At least it may be safely affirmed that no astronomer discovering the object in its present state would, after viewing it through a prism, hesitate to pronounce as to its present nebulous character. Judging from the brightness of the star in the finders of $3\frac{3}{4}$ inch aperture it is probable that a refractor of 5 inches aperture would be sufficient to show the monochromatic nature of its light when viewed through a small direct-vision prism.

3. *The Report of Professor Pickering, Director of the Harvard College Observatory*, to the Visitors, Nov. 26, 1877, has been published. It has been decided to devote the large refractor to photometric work and some results of general interest have been already obtained. After describing the photometric arrangements and the details of some observations upon the satellites of Mars, the Director adds: these observations have not yet been wholly reduced, it is therefore impossible to give the final conclusion. The best idea of the light of a satellite is obtained by giving the diameter to which the primary must be reduced to render it no brighter than the satellite, or the diameter of the latter, if it reflected light in the same proportion as the planet. This is, in fact, probably the only estimate we can ever make of the true diameter of these bodies. An approximate reduction of the measurements of the outer satellite, comparing its light with that from the holes, gives its equivalent diameter at about 5·9 miles. The result of the other comparison is about 5·4 miles. This agreement is all that could be desired. The observations of the inner satellite give its diameter as 6·5 miles. The direct comparison of the two gives their relative diameters as in the ratio of 10 to 9. These figures will be somewhat altered in the final reduction. As the darker color of the outer satellite somewhat diminishes its light, it is probably safe to call it about six miles in diameter, and the inner satellite seven miles. . . .

This photometer has since been used upon various other objects. A large number of measurements of seven of the satellites of Saturn have been obtained, including the very faint object

Hyperion, whose light is thus determined with great precision. Numerous other very faint objects have been similarly measured, especially some minute companions to bright stars. Standards will thus be established for the fainter stars, with which observers hereafter can compare other minute objects. Several asteroids have been compared in like manner, and will give some reliable data regarding the true diameters of these bodies.

V. Miscellaneous Scientific Intelligence.

1. *Norwegian Exploring Expedition.*—The Norwegian Atlantic exploring expedition returned to Tromsöe, in Norway, by latest advices, for the purpose of refitting for the further prosecution of its work, the first period having occupied from the 13th of June until the 8th of July. It will be remembered that the object of this exploration is the discovery not merely of the more important facts in regard to the physics and natural history of the northern seas, but also of making an economical application of the same in connection with the Norwegian fisheries, which constitute so important an element in the prosperity of that nation. This is only a continuation of the enlightened measures initiated by the government of Norway many years ago, upon the results of which, indeed, we are obliged to depend for most of our information in regard to the natural history and economy of the herring, mackerel, cod and other northern fish.

An interesting point established by this first cruise of the *Vöringen*, the vessel employed, is that the minimum of temperature is not always at the bottom of the water, but often at a certain depth near the surface, its distance therefrom varying with the season or other circumstances. In the West Fiord the temperature at the surface was 45·7°; this decreased to 38·8° in sixty fathoms; and then in 140 fathoms, ten fathoms above the bottom, it rose to 41°. The explanation of this phenomenon appears to be that in winter the air is generally cooler than the sea surface, and the layers of surface water being chilled and becoming denser, sink down to a certain level, below which the temperature then usually increases with the depth. In the spring and summer the air at the surface is warmer, and the surface layer of water has no further tendency to sink. This maintains a cold stratum persistently between the surface and the bottom, which continues until by the action of storms or currents an equilibrium to a certain extent is effected.

The greatest depth found during the cruise was 1710 fathoms, with a bottom temperature of 28·4°, the lowest yet found by the expedition.—*Harper's Weekly, October* 27, 1877.

2. *Translation of Weisbach's Mechanics.*—Professor DuBois has translated that part of volume second, section second of Weisbach's Mechanics that treats of *Hydraulics and Hydraulic Motors.* Though complete in itself it is also intended as a continuation of Coxe's translation of volume I, and it is to be soon followed by a translation of that part of volume II that treats of *Heat, Steam and the Steam Engine.* It is hoped that the transla-

tion of volume III will soon follow. The part now issued forms a volume of lviii and 675 pages. It is published by J. Wiley & Sons.

3. *A new Treatise on Steam Engineering, Physical properties of permanent Gases, and of different kinds of Vapor;* by JOHN W. NYSTROM, C.E. 185 pp. 8vo. New York, 1876. (G. P. Putnam's Sons.)—This work contains many formulas and tables relating to combustion, steam pressure and so on, which will be useful to the practical engineer. The author makes a vigorous attack upon many of the commonly accepted terms in mechanics, as he has done in his Elements of Mechanics. A large number of new symbols and characters are introduced, the desirability of some of which may perhaps be questioned.

4. *A List of Writings relating to the Method of Least Squares,* with historical and critical notes; by MANSFIELD MERRIMAN. 82 pp. 8vo. (From the Trans. of the Conn. Acad. of Science.)—In this memoir Mr. Merriman gives over 400 titles of volumes or memoirs relating to the Method of Least Squares, beginning with Cote's rule, published in 1722, and ending with the year 1876. The work is however not a mere list of titles. He has given notes upon and abstracts of all the more important papers. About one-fifth of the titles are quoted at second hand. These are in general those of works of minor importance. The rest he has been able to examine in the libraries of Yale College. The preparation of this list with the criticisms of papers is a contribution of great value to exact science.

5. *Elements of the Method of Least Squares;* by MANSFIELD MERRIMAN. 198 pp. 8vo. London, 1877. (Macmillan & Co.)—Mr. Merriman treats the subject of Least Squares in two sections. In the first he introduces the least amount of theory possible, the object being to give and explain the practical rules. In the second he develops the theory.

6. *Royal Society.*—In their award of medals for the present year, the Council of the Royal Society have taken a wide view, for four of the five men chosen for the honor are foreigners. The Copley medal goes to Professor J. D. Dana, of New Haven, Conn., for his biological, geological, and mineralogical investigations, carried on through half a century, and for the valuable works in which his conclusions have been published. Mr. F. A. Abel, F.R.S., the newly created C.B., is to have a Royal Medal for his physico-chemical researches on gun cotton and explosive agents; and when we bear in mind the diligence and intelligence with which these researches have been carried out during many years, and the admirable papers thereupon published in the Philosophical Transactions, we may safely predict that this award will be generally approved. A Royal Medal is awarded to Professor Oswald Heer, of Zurich, for his numerous researches and writings on the Tertiary plants of Europe, of the North Atlantic, North Asia, and North America, and for his able generalizations respecting their affinities and their geological and climatic relations. For the first award of the Davy Medal, Robert Wilhelm Bunsen, of Heidelberg, and Gustav Robert Kirchoff, of Berlin, are selected,

in recognition of their researches and discoveries in spectrum analysis. This is a good beginning with a medal which is, perhaps, destined to become famous in the history of science. There will be no question as regards the custody of the golden prize, for each of the two learned professors will have a medal.—*Athenæum.*

The Silver Country or the Great Southwest. A review of the Mineral and other wealth, the attractions and material development of the former kingdom of New Spain, comprising Mexico and the Mexican Cessions to the United States in 1848, and 1853, by A. D. Anderson. 221 pp. 8vo. New York, 1877. (G. P. Putnam's Sons).

Journal of the American Electrical Society; including original and selected papers on Telegraphy and Electrical Science. Vol. i, No. 2, Chicago, 1877.

OBITUARY.

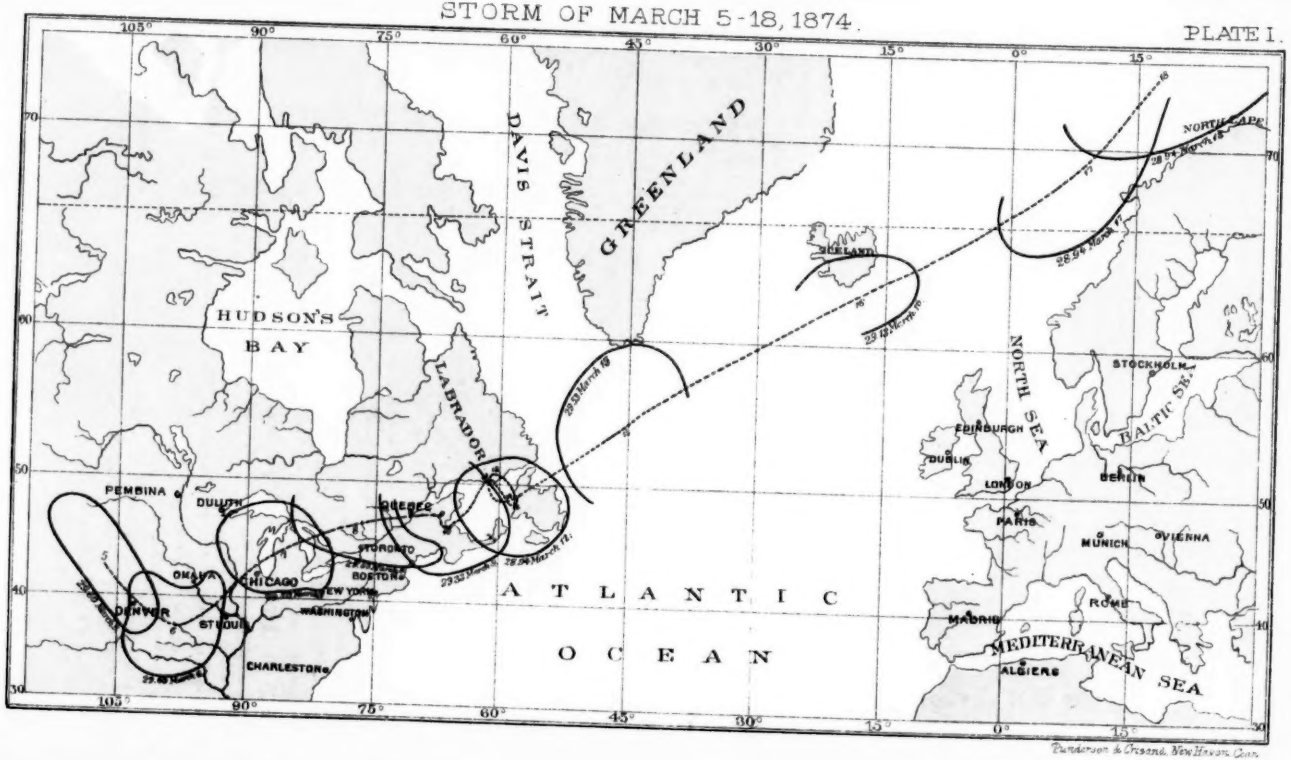
JARED POTTER KIRTLAND, M.D., LL.D.—Dr. Kirtland died at his residence in East Rockfort (near Cleveland), Ohio, December 10, 1877, at the advanced age of eighty-four years, having been born in Wallingford, Connecticut, November 10th, 1793. In scientific research and study Dr. Kirtland devoted himself especially to general natural history and zoology. His discovery of the existence of sex among the Naiades of North America was announced by his paper in volume xxxvi (1834), of this Journal. This important observation has since been fully confirmed by others, although for a time sharply contested. He also first noticed that the young of the Naiades soon after escaping from the mother are attached to some fixed object by a byssus and for the first year of their lives become selsite, (this Journal, (I) xxxix, 164) Dr. Kirtland removed to Ohio in 1823, having graduated in medicine at Yale College in 1815. He conducted the survey of the Natural History of Ohio under the first Geological survey of that State in 1848. The large collections then made at his own cost he subsequently devoted to founding the Cleveland Academy of Natural History, the State of Ohio refusing to reimburse him the expenses of the collection. His catalogues of the fishes, reptiles, mollusks and birds of Ohio form part of the published results of that survey, and subsequently his descriptions of the fishes with figures drawn by his own hand were published in the Journal of the Boston Society of Natural History.

Dr. Kirtland was a man of untiring industry, devoted to the duties of an arduous practice in medicine, and those of a professor of the theory and practice of his art in more than one Medical College. He was a zealous cultivator of plants and was successful in producing many new varieties of fruits. His large and generous nature made him a philanthropist and patriot and endeared him to a large circle of admiring friends, to whom his stores of exact and varied knowledge afforded an unfailing source of enjoyment. He retained his intellectual powers undimmed to the close of his long life.

Dr. Kirtland was one of the subscribers to the first issue of this Journal in 1818, and his name has stood on its books to the close of the last year, being, so far as appears, the last member of that original number. B. S.

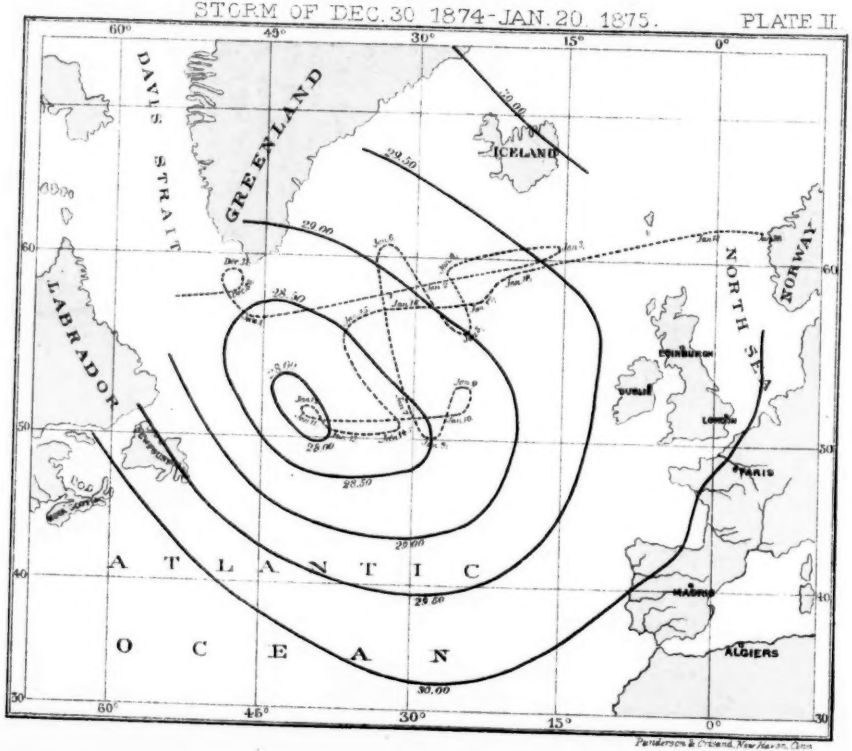
STORM OF MARCH 5-18, 1874.

PLATE I.



Punderson & Orcutt, New Haven, Conn.

STORM OF DEC. 30 1874 - JAN. 20 1875. PLATE II.



Published by Blodgett, New Haven, Conn.